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LONG-TERM FORECASTS FOR THE NIAGARA RIVER FLOWS

Report No 88-327-K

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ABSTRACT

An assessment study of the forecasting model used by Ontario Hydro to obtain six-years-ahead forecasts for the Niagara River flows was carried out. The objective of the study was to evaluate the forecast ability of the model and to determine if the model could be improved upon. A forecasting competition is used, with the root mean square error (RMSE) as the index of the forecast ability. A total of 33 models and 18 validation periods are included in the competition. The results indicate a strong dependency of the performance of the models on the type and length of the validation period. Based on the results for the longest validation period it is found that: (i) either the routing model alone or a combination of the routing and the periodic autoregressive models can improve the current model; and (ii) for either of these models, the RMSE values of the forecasts for the first year are between 20% to 40% smaller than the corresponding RMSE values obtained by a model whose forecasts are based only on the long-term monthly means; however, these improvements rapidly diminish as the forecast period increases.

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To: Dr. Don Mills
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LONG-TERM FORECASTS FOR THE NIAGARA RIVER FLOWS

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1. INTRODUCTION

Ontario Hydro (OH) periodically prepares six-years-ahead forecasts for the Niagara River flows. These forecasts are used to plan the usage of the water resources during the operation of the OH's electrical system. To improve the efficiency of the planning tools, the Civil Works Department of the Thermal and Hydraulic Generation Division has requested an assessment study of the forecasting model used by OH. The objectives of the study were (i) to evaluate the forecast ability of the model and (ii) to improve the forecasting model, if possible.

To assess the forecast ability of the models, a forecasting competition was devised. In the competition the forecasts of the OH model were compared with the forecasts obtained with other methods. Several competition studies have been presented in the literature (see Noakes, *et al*, 1988; Noakes *et al* 1985). However, these studies concentrate on the comparison of one-step-ahead forecasts and the author is not aware of any attempt to investigate the long-term (six-years-ahead) forecast performance of any model.

There are many forecasting methods that could have been included in the competition, ranging from simple guesses to very sophisticated mathematical models. The mathematical models are derived using different approaches. Some concentrate on formulating the equations governing the physical properties of the system that explain future events (physical models). Others concentrate on identifying patterns in the historical data and expressing them in abstract mathematical equations (empirical or statistical models). Usually the physical models have sound theoretical justification, but sometimes they are inadequate for forecasting since they may require input data that is not directly available and has to be estimated or forecasted in some other way before the model can be used. The empirical models do not have difficulty in obtaining the required data, but they may lack physical interpretation.

To avoid a lengthy model selection process, it was decided to include in the competition only some of the models that have demonstrated adequate performance in forecasting geophysical time series.

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The next section provides a general discussion of the approach used in the study. Section 3 describes the models that were used in the assessment. Section 4 presents the methodology used for the assessment of the forecast ability of the models. Section 5 presents the results together with some discussion. The last Section gives some conclusions and recommendations. Appendix A presents additional discussion of the updated means. Appendix B presents the complete set of results obtained for the validation period 1961 to 1987. Finally, Appendix C present the computer program developed for obtaining the results presented in this study.

2. BASIC APPROACH

To appreciate the value of the competition, it is necessary to keep in mind that it is unrealistic to expect that a forecast model will produce exact predictions. There will always be errors. A good forecast model tries to minimize these errors. However, it is not known what is the minimum attainable bound. By carrying out a competition it is possible to determine the lowest error for the models included in the study and the relative merits of each one of them.

In a more general framework, a forecasting model minimizes a loss function which take into account the magnitude and direction of the errors. The magnitude of the loss function provides an index for evaluating the forecast ability of the model. In the absence of a priori knowledge of a loss function, the root mean square forecast error (RMSE) represents an index with reasonable compromise (see Noakes, *et al* 1988, 1985). In this study the evaluation of the forecast model is done using the RMSE. The RMSE values are calculated in the following way: (i) the historical data set is divided in two periods, and the parameters of the models are calculated using the initial (estimation) period; (ii) for each year of the last (validation) period of data, monthly six-years-ahead forecasts are calculated, together with the corresponding forecast errors (defined as the difference between the actual observations and the forecasts); (iii) the monthly means of the squared forecast errors are calculated; and (iv) the square root of the means are computed.

To determine the performance of a model, it is necessary to have reference landmarks for the acceptable magnitude of the forecasting errors. Two characteristics are required for the landmarks: (i) that they be easily calculated for any series; and (ii) that they have some meaning regarding the forecast ability of a series. The landmarks for the present study are the RMSE values obtained by a model whose forecasts are based only on the long-term (historical) monthly means. The long-term monthly means are calculated using all the available data up to the time of forecast as opposed to the calculation of the means using only few observations prior to the time of forecast. The RMSE values of the above model are denoted as MRMSE. It is easy to check that the MRMSE landmarks meet the above conditions: certainly, they are easily calculated, and for a given series, they measure the ability of the monthly means to perform as predictors. The MRMSE values can be used as yardsticks: models in the competition with RMSE values that are always larger than the MRMSE should be discarded and only those that perform better retained (or else, the MRMSE values could be used as "best" forecasts). Note that the reduction over the MRMSE provides an adequate index of the forecast ability of a model.

Because in this analysis the assessment of the models depends on the RMSE, it is very important to have an adequate method for estimating this value. For some mathematical models it is possible to analytically calculate the RMSE, but in general this is not the case. Furthermore, even if it was possible, but if the model does not completely conform with the as-

sumptions required by the mathematical model, the estimation of the RMSE may be biased. Under these circumstances, the best way to estimate the RMSE is by a direct comparison of the forecasts with the historical values. To have adequate estimates, it is necessary that the data used in the calculation of the RMSE should not be used in the calibration of the models.

In the Niagara River forecast model a total of 72 monthly periods are forecasted (monthly forecasts for 6 years). This creates some difficulties in the assessment of the model because it is not possible to obtain a single index of the forecast ability of the model. Note that it is not legitimate to incorporate all the forecasts errors into a single index (which allow a total ranking of competing models) because different periods produce deferent types of forecast errors. Also note that when several models are compared, it may not be possible to find a ranking of the models that is consistent for all forecast periods. Some ad-hoc procedures are then necessary to obtain a final ranking.

3. MODELS

3.1 General

As was mentioned in the introduction there are many models that could be used to obtain the Niagara River flow forecasts. For the present study three basic types of models were selected: (i) a routing model that forecast Lake Erie elevations together with a method to transform the results into Niagara River flow forecasts (Quinn, 1978; Hartmann 1987); (ii) a spectral model (Cohn and Robinson, 1976); and (iii) a periodic autoregression (PAR) model (Veccihia, 1985; Noakes, *et al*, 1983; Pagano, 1978). A combination of the first two models was used by OH to obtain the forecasts and so they had to be included in the competition. The PAR model was included because it has performed quite well in other forecast competitions (see, Noakes, *et al*, 1983; Thompstone, *et al*, 1985).

Other time series approaches, like the autoregressive moving average (ARMA) model, the deseasonalized ARMA and the transfer function noise model (TFN) have been proposed in the literature for forecasting river flows (see Salas, *et al*, 1980; Noakes, *et al*, 1983; Thompstone, *et al*, 1985). The ARMA models were initially considered for inclusion in this study, but early experiments did not show promising results, so they were disregarded in further analysis. TFN models were not included in the analysis because they require additional data that were not available.

A perusal of the historical Lake Erie series reveals that the long-term mean of the series is slowly drifting. This fact suggested a modification of the models to include a mean updating technique in the estimation and calibration of the models. Combining the mean updating technique with the basic models resulted in 33 models that were included in the study.

3.2 Routing Model

The routing model is based on an Hydrologic Response Model (HRM) developed by Quinn (1978). This was latter modified at the Great Lakes Environmental Research Laboratory (GLERL) by Hartmann (1987). The model was developed to calculate "the hydrological response of the North America Great Lakes and their connected channels." The input parameters include over-lake precipitation, basin run-off, lake evaporation, diversions rates for each lake in the system, St. Mary's River flows, and ice retardation of the flows. The model outputs are end-of-month and monthly mean water levels for each lake in the system

and the monthly mean flow rates in the connecting channels. The equations set for the model is composed of the continuity equations for each lake in the system and a discharge equation for each channel. The continuity equations solved by the program are of the form:

$$0.5(I_1 + I_2)t + 0.5(O_1 + O_2)t = S_1 - S_2$$

where I = the rate of inflow to a lake, O = the rate of outflow from a lake, S = the storage volume of a lake, t = the specified time interval, and the subscripts 1 and 2 = the beginning and the end of the time interval, respectively. The discharge equations are different for the summer and the winter months to take into account the ice retardation factors of the system. These equations were calibrated by Hartmann using data from 1962 to 1980. The equations are solved using a second order difference equation technique that does not require iterations. Details are given in Hartmann, 1987.

One disadvantage of this model is that it requires the forecasts of the input parameters. For a short term forecast, some of the input parameters can be accurately estimated but for long-term forecasts, the accuracy of the input parameters is questionable. This reduces the accuracy of long-term forecast. In this study the input parameters were set at the median values of the historical information from 1962 to 1985.

The original routing model used by OH (*Old* routing model) was one developed by the Great Lakes Study Office of Environment Canada. Technically, the Old model is similar to the HRM model. However, the input facility of the computer package is not as flexible as the HRM model. The input facility of the HRM model allows the user to carry out contingency studies of the effect of different precipitation and run off values on the forecasts. This tool is very useful. For this reason the Civil Works Department decided to replace the Old routing model by the HRM model. The change occurred in the middle of the present study. At that time it was decided to include both models in the study.

3.3 Spectral Analysis Model

The spectral model was developed by Cohn and Robinson (1976). The model can be expressed as a trigonometric polynomial of the form:

$$y_t = \beta_0 + \sum_{i=1}^{k} [\alpha_i \sin(2\pi f_i t) + \beta_i \cos(2\pi f_i t)] + \epsilon_t$$

where the α_i and the β_i are coefficients, the f_i are the frequencies of the model, and the ϵ_t is an error term, assumed to have zero mean and constant variance σ^2. Six frequencies with cycles are 1, 8, 11, 22, 36, and 100 years are included in the model. The first five cycles were identified by Cohn and Robinson (1976) and the long cycle was included because the data give some indication of its presence. The assumption behind the model is that the events repeat themselves with periodicities determined by the value of the frequencies.

The Niagara River flows forecasts can be obtained in two ways. One is to fit a spectral model to forecast Lake Erie elevations and then use a transfer function model to obtain the Niagara River flows. The other is to fit the spectral model directly to the Niagara River flows. These two models were included in the study. The coefficients were estimated using ordinary least square (OLS) algorithms (Abraham and Ledolter, 1983)

3.4 Periodic Autoregressive Model (PAR)

The PAR model was proposed by Pagano (1978) and has been suggested by several authors as an appropriate model to forecast monthly river flow series (Noakes, *et al*, 1988; Noakes, McLeod and Hipel, 1988, 1983; Veccihia, 1985). This model expresses the values $y_{t,m}$ of the m^{th} month of the t^{th} year as a function of the values observed in the previous months:

$$y_{t,m} - \mu_m = \sum_{i=1}^{k_m} \beta_{m,i}(y_{t,m-i} - \mu_{m-i}) + \epsilon_{t,m}$$

where μ_m m=1,...12 are the mean monthly values, $\beta_{m,i}$ i = 1,...,k_m, m=1,...,12 are coefficients and $\epsilon_{t,m}$ is a series of error terms assumed to be independent random variables with zero mean and σ^2_m variance. The advantage of the model is that it allows to fit different dynamics to each monthly period.

The maximum lag included in each month is called the order of the month. The collection of these orders form a vector that is referred to as the order of the model. In practice, the order of the model is not known and has to be identified from the available data. In this study two options were considered. One was to fix the order to one (1) parameter for each month (preliminary analysis suggested that one lag per month captured the majority of the dynamics on the data). The other was to use an automatic order identification procedure. The automatic order identification was done by minimizing the Akaiki information criteria (AIC) (Akaiki, 1974). For a given model, the AIC is a function that combines information of the goodness of fit and the number of parameters included in the model. When large amounts of data are available, the AIC provides the correct orders of the model. When small amounts of data are available, the order identified using the AIC may depend on the length of period used to fit the model. After the order of the model was identified, the coefficients were estimated using the McLeod-Hipel Time Series computer Package (McLeod and Hipel, 1989).

3.5 Mean Update

One of the main assumptions in the formulation of the previous models is that the river flows are stationary (i.e. that the pattern of any two segments of data look basically the same). However, an examination of the data reveals the presence of dry and wet periods which suggests that the stationarity assumption may be invalid. Fortunately, if the data are not stationary, it is possible to remove the fluctuation between dry and wet periods transforming in this way the original data into a stationary series.

The stationarity assumption is examined in Figure 1 which compares the annual average values of the Niagara River flows with two other series: the series of the *long*-term means and the series of the *short*-term means. The long-term mean at time t is defined as the average of the t previous observations. The short-term means at time t is defined as the run-average of k ($k < t$) observations, ie. the mean of y_{t-i}, i = 0, ..., k-1. In Figure 1, k = 10. It can be observed form the Figure that the plot of the short-term means deviates from that of the long-term means.

The effect of the change in means is also observed in the forecast values, particularly those obtained using the PAR model. Preliminary analyses indicated that when the models are compared using data from 1961 to 1984, models using long-term means produce forecasts

with larger errors than models using short-term or updated means. This led to an expansion of the class of models used in the study to include the option of transforming the data to induce stationarity. This was achieved by using short-term or updated means.

The long-term means for month m of year t, are defined as the long-term means of the series $y_{k,m}$, $k=1,...t$ (i.e. the means of the observations available for month m). The updated means are calculated using either exponential smoothing or run-averages. The exponential smoothing means at month m of year t, $Y_{t,m}$, is $Y_{t,m} = (1-\alpha)Y_{t-1,m} + \alpha y_{t,m}$, where $0 < \alpha < 1$. The parameter α is called the smoothing parameter. Note that as α increases more weight is given to recent observations and so the updated mean tends to follow closer the observations. On the other hand, as α decreases, the updated means follows closer the long-term mean. Additional information of the different estimators is given in Appendix A.

4. ASSESSMENT METHODOLOGY

4.1 General

A forecast competition was designed to study the forecast ability of the forecasting model. The competition consisted of a comparison of the RMSE value of several models with the RMSE of the model whose forecasts are the monthly long-term means: MRMSE. This approach provides two benefits: (i) the value (1 - RMSE/MRMSE) provides a readily available index of the forecast ability of a model; and (ii) the results of the competition provide material that can be used to decide how much could the forecast model be improved.

4.2 Data

The data used in the study were: (i) the monthly average Lake Erie elevations at Cleveland, from January 1860 to June 1988; (ii) the Niagara River flows at Queenston, from January 1860 to June 1988; and (iii) the median values, based on the historical information from 1962 to 1985, for: over-lake precipitation for Lakes Michigan-Huron, St. Clair and Erie; basin run-off for Lakes Michigan-Huron, St. Clair and Erie; lake evaporation values for Lakes Michigan-Huron, St. Clair and Erie; diversions rates for the Lakes at Chicago and at the Welland Canal; St. Mary's River flows; and ice retardation of the flows at St. Clair, Detroit and Niagara Rivers.

The Niagara River data set was divided in two periods: the estimation period and the validation period. The estimation period consisted of the initial segment of the data and was used to calibrate the parameters of the Niagara River's spectral and PAR models. The validation period was used for the calculation of the RMSE of all the models. Several validation periods were included in the study.

The data of the Lake Erie elevations correspondent to the estimation periods selected for the Niagara River flows were used in the estimation of the Lake Erie's spectral and PAR models. The fitted models forecasted Lake Erie elevations which were converted into Niagara River flows by applying monthly conversion factors estimated from the complete data set. The validation period of the Niagara River data was then used to calculate the RMSE of these models.

The median values were used to set the input values required by the routing model. These were kept fixed for all the validation periods included in the study. The forecasts obtained were compared with the validation periods of the Niagara River data to estimate the RMSE of the model.

4.3 Calculation of the RMSE

For each selection of estimation/validation period of the Niagara River data, the following procedure was used for the estimation of the RMSE of a given model. For simplification, the validation period is taken from January 1961 to June 1988. The changes for other validation periods are obvious. In the following, $y_{t,m}$ denotes the observation for the m^{th} month of year t; $y_{t,m}(r)$ denotes the the r-step ahead forecast made at the m^{th} month of year t; $RMSE_i(r)$ denotes the RMSE value for the r-step ahead starting in month i^{th}, ie. the RMSE value associated with the forecasts $y_{t,i-1}(r)$, with $y_{t,i-1+r}$ in the validation period.

1. At each December from 1960 to 1987 the six-years-ahead monthly forecasts, $y_{t,12}(r)$, r = 1,2,...,72, t = 1960, ..., 1987, were calculated.

2. The forecasts were compared with the actual observations, $y_{t,12+r}$, to obtain the forecast errors $e_{t,12}(r) = y_{t,12+r} - y_{t,12}(r)$, r = 1,2,...,72, t = 1960, ... ,1987, associated with the model. If $y_{t,12+r}$ was not available, $e_{t,12}(r)$ was not defined. Here $y_{t,12+r} = y_{t+k,i}$ where r = 12(k-1) + i, where $1 \le i \le 12$.

3. The RMSE for the r-month ahead forecast starting in January, $RMSE_1(r)$, r = 1,..., 72 was calculated as the square root of the mean square forecast errors MSFE(r), where

   $$MSFE(r) = \sum e_{t,12}^2(r)/n(r).$$

   The sum extends over the n(r) effective number of forecasts errors for period r. In this example, n(1) = 28, ..., n(6) = 28, n(7) = 27, ..., n(19) = 27, ..., n(72) = 23.

Several comments regarding the $RMSE_i(r)$, i = 1, ..., 12, r = 1,...,72 are made below to help the reader in understanding the meaning of the indexes.

1. The $RMSE_i(r)$ depends on the initial forecast period, i, and the number of steps ahead, r. Note that $RMSE_i(r)$ is an estimate of the magnitude of the forecast errors made for the 12^{th} month (December) if i+r is divisible by 12, and for the k^{th} month, where k is the residual of dividing i+r by 12, otherwise.

2. In general $RMSE_i(r) \neq RMSE_j(r)$ if $i \neq j$. Note that the RMSEs correspond to estimates of the standard deviations for two different months, and in general, different months will have different forecast errors.

3. It is expected that $RMSE_i(r) \le RMSE_i(r+12)$. In this case the RMSEs refer to the same month but $RMSE_i(r+12)$ is for forecasts one year latter than those for $RMSE_i(12)$, therefore expected to be larger. However, because the number of effective observations entering in the calculation of $RMSE_i(12+r)$ is one less than the number of effective observations used for $RMSE_i(r)$, the inequality can go in the other direction.

4. In general $RMSE_i(r)$ and $RMSE_i(r+1)$ can not be compared a priori. Note that although $RMSE_i(r+1)$ corresponds to a further ahead forecast than $RMSE_i(r)$, they refer to different months.

5. Values of $RMSE_i(r)$ and $RMSE_i'(r)$ corresponding to validation periods V and V' estimate the same quantity (note that both validation periods start at the same month, but not necessarily at the same year). In this case differences between the RMSE values can be observed due to (i) differences in the length of the validation periods and (ii) differences in the water regimen of the validation periods (ie. one may be a wet period and the other dry).

5. RESULTS

5.1 Cases in the Study

As explained in Section 4, the calculation of the RMSE values of a given model depends on several factors, such as the initial forecast period, the forecast month and the validation period. Therefore, to be able to make solid conclusions from the results of this study, it was necessary to study the sensitivity of the results with respect to these factors. To study the effect of the length , the water regime and the initial month of the validation period on the RMSE estimates, different cases were considered in the study. These are listed in Table 1.

Besides the length and type of the validation period, three other factors can affect the values of the RMSE for a given type of model: (i) the mean updating technique (see Section 3.5); (ii) whether the model is fitted to the Lake Erie elevations or to the Niagara River flows; and (iii) whether or not the parameters of the model are updated with the data available in the validation period. The values of the RMSE of the PAR models are also affected by the number of monthly coefficients included in the model (i.e by the order of the periodic model). The combinations of all these factors provide a combinatorial explosion of cases that could have been considered in the study. However, due to a limitation of resources, only few cases were included. These are listed in Table 2.

It should be pointed out that the RMSE results for the routing models during validation periods containing years between 1965 and 1985 may be biased. The reason for this bias is that the input values were based on the historical information of this period, so that the RMSE may represent a goodness of fit rather than a validation index. On the other hand, the input values were set at the median levels and so they did not allow the inclusion of information that could enhance the short-term forecasts. Due to the lack of additional data it was not possible to correct for this bias. However, it was not expected that the magnitude of the bias could significantly affect the results. Furthermore, because several validation periods were included in the study, the performance of the routing model could be judged by the consistency of its results.

5.2 Results for Validation Period 61(1) to 84(12)

The first set of analyses was carried out for the validation period 61(1) to 84(12). The models NEWR, F05 and F15 were not included in these analyses. The complete results are given in Appendix B. These include the RMSE values for all forecast periods, as well as the ranking of the models by RMSE value at each period. In general, it was observed (i) that the

relative performance of the models varies with the forecast period; and (ii) that it was possible to improve upon the model used by OH. In particular, it was observed that the spectral model did not perform adequately.

Table 3 lists the model with the smallest RMSE at each forecast period. It can be seen that not a single model gives the smallest RMSE for the whole period, although the PAR with ES(0.5) seems to perform the best. If a model was to be selected based on these results, a combination of models would have been recommended. To simplify the final model, a maximum of two models would have been included: the routing and the PAR with ES(0.5).

The combination of the Routing and the PAR models was further considered to study how the model would operate if implemented. Two main issues were investigated: (i) the transition period from the routing to the PAR model; and (ii) the consistency of the forecasts (i.e. how do the forecasts change as data become available).

Several difficulties were found with the use of the combined model during 1987 and 1988: (i) an increase in the forecast levels for the month of December that was larger than the historical observed trend; this was alleviated, without affecting significantly the RMSE value of the forecasting model, by using a different mean updating technique in the PAR model; (ii) an abrupt change of the forecast levels from the routing model to the PAR that did not have any physical meaning; this problem arises because of the different methods used by the models to estimate the long-term mean of the series; it was not possible to alleviate this problem during the duration of the study; and (iii) in contrast with the old model used by OH (a combination of the Routing and the spectral models), the forecasts of the proposed model showed either a long-term increase or a a long-term decrease with no turnaround on the water levels. These difficulties motivated a deeper look into the evaluation of the models. In particular, they suggested an analysis of the RMSE during different water regimens.

5.3 Results for the 20-, 30-, 40- and 50-Year Validation Periods

Given the experience gained with the analysis of the 24 years validation period 61(1) to 84(12), it was decided to concentrate the remaining analyses on models F0, F05, F15, ROUT and NEWR. The spectral analysis model was not included in this part of the competition because some of the estimation periods did not have enough data to estimate the long term frequencies of the model.

The results are presented graphically on Figures 2 to 11. Each figure presents the plots of the RMSE of the 72 forecast periods for the five models together with the plot of the MRMSE. The following observations can be made.

(i) The initial month of the forecasts does not seem to have a significant effect on the overall results.

(ii) For RMSE calculated using 20 or 30 years of data, the water regime during the validation period has a significant effect on the results.

(iii) As the number of years used in the calculation of the RMSE increases, the results are more consistent and give a different picture than the results obtained using 20 or 30 years.

(iv) Based on the results obtained with 50 years of data, it is observed that with the models included in this study, a maximum of 20% to 40% reduction over the MRMSE can be obtained. This maximum reduction is for the first year-ahead forecasts; this value diminishes as the forecast period increases, and after the third year, there does not seem to be any significant advantage of the forecast models over the long-term mean.

5.4 Discussion

To understand the differences in the results obtained at different validation periods, it is necessary to analyze more closely the series of events in each period and the nature of each model. With the aid of Figure 1 the following observations about the validation periods can be made.

(i) From 1968 to 1987: the water levels stayed above the long-term mean; this period included the high record of the series, and at the end of the period there was no indication that the river flows were returning to the long-term mean.

(ii) From 1942 to 1961: the water levels went up from below the long-term mean, remained above for few years, and came back again.

(iii) From 1958 to 1987: the series started below the long-term mean and went down a little before rising above the long-term mean to remain there.

(iv) Form 1932 to 1961: the series started below the long-term mean, went down to the record low and then followed the pattern described above for 1942 to 1961.

(v) From 1948 to 1987: the series started at the long-term mean, went up a little, then came down into a dry period of about 10 years, and finally went up above the long-term mean and remained there.

(vi) From 1938 to 1987: the series started at a dry period, went up, came down and went up again to remain there.

The long-term forecasts of the routing model converge to the long-term mean of the series, adjusted by the water regime specified with the input values to the model. So, due to the way the input values were specified for the model, the following results were expected: for the validation period from 1968 to 1987, the long-term forecasts of the model should be better than the long-term mean. For 1948 to 1968, the routing model could be worst than the long-term mean. For longer validation periods, the bias of the RMSE were expected to be in favor of the model.

The long-term forecasts of the PAR model tend to the long-term mean of the models. The long-term means of models F05 and F15 are calculated based on exponential smoothing and run-of-averages which adapt to the changing levels. However, this adaptation is not immediate, but it takes the updated means a few years to respond to the changes (see the plot of the updated means in Figure 1). If the water levels oscillate during a validation period, the updated means will *follow* the series, without leveling with it, so that the long-term forecast of F05 and F15 may be worst than the long-term means. If the water levels off during a validation period, the updated means will level off with the series and so the long-term forecasts of F05 and F15 will tend to be better than the long-term means. Note also that the long-term forecasts of F0 will always be at least as good as the long-term means.

A cross analysis of the description of the validation periods with the description of the behavior of the long-term forecasts of the models describe the main features observed in Figures 2 to 11.

6. CONCLUSIONS AND RECOMMENDATIONS

Based on a validation period from 1938 to 1987, the following conclusions can be made.

(i) It is possible to slightly improve the model used by Ontario Hydro, particularly the long term forecasts. This can be achieved by using either the routing model alone, or a combination of the routing and the periodic autoregressive models with updated means, or a combination of the routing model and the long-term means. However, since there is no significant difference in the forecast ability of the three models, the easiest method (i.e using the routing model during the six-year period) would be preferable.

(ii) With respect to the forecast ability of the models, an improvement between 20% to 40% over the forecasts based on the long-term means can be obtained. These maximum values are for the first year-ahead forecasts. These values diminish as the forecast period increases, and after the third year, there does not seem to be any significant advantage of the forecasting models over the long-term mean.

As indicated before, the input values for the routing model are based on data collected between 1962 and 1985. This corresponds to a wet period and therefore the data may be biased for other water regimens. It is therefore recommended to update the data base of the routing model as data become available.

The most interesting result of the analysis is the astonishing dependency of the assessment results on the type and length of the validation periods. For validation periods with large number of years (40 or more), the results did not indicate a significant difference in the performance of the forecasting models. This sharply contrast with the results observed for short validation periods (30 years or less). In these cases the results depended on the flow levels of the validation periods, and significant differences among the models can be observed. These results question the hypothesis of stationarity of the series assumed by some models. They also introduce difficulties in the definition of an adequate index to compare the forecast ability of the models. The conclusions of this study are based on the results of the long validation periods on the grounds that these results are robust with respect to the behavior of the series.

The results of the study also indicate that the success of a forecasting model for more than two- or three-years-ahead depends on how well the model captures the *long-term variability of the water levels*. Unfortunately, there is a lack of understanding of the mechanisms that govern this process. Furthermore, empirical approaches (like the spectral model) do not perform adequately at present, perhaps because the historical records are not large enough to properly identify long-term cycles in the series.

Finally, it is observed that the lack of data did not allow a comprehensive study of the spectral analysis in the competition. For this reason, it is recommended to perform periodic evaluations of the spectral model as more historical data become available.

Approved:

for A. H. Chung
Manager
Operations Research Department

Submitted:

F. Camacho
Mathematician
Reliability and Statistics Section

FC:cmh

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TABLE 1

List of Validation Periods Included in the Stuty*

	DRY PERIOD	WET PERIOD
20 years	68(1) to 87(12)	42(1) to 61(12)
	67(9) to 87(8)	41(6) to 61(5)
	68(6) to 88(5)	41(3) to 61(2)
	68(3) to 88(2)	
24 years	61(1) to 84(12)	
30 years	58(1) to 87(12)	32(1) to 61(12)
	58(6) to 88(5)	31(6) to 61(5)

	DRY/WET PERIOD
40 years	48(1) to 87(12)
	48(3) to 88(2)
	48(6) to 88(5)
	47(9) to 87(8)
50 years	38(1) to 87(12)
	38(6) to 88(5)

YY(m) idicates the m^{th} month of 19YY.

TABLE 2

List of Models Include in the Stuty

	MODEL	TYPE	MEANS	ORDER	UPDATE*	DATA
1.	N0N=(F0)	PAR	Long term	AIC	No	Niagara
2.	N00	PAR	Long term	AIC	Yes	Niagara
3.	N01	PAR	ES(0.1)**	AIC	Yes	Niagara
4.	N02	PAR	ES(0.2)	AIC	Yes	Niagara
5.	N03	PAR	ES(0.3)	AIC	Yes	Niagara
6.	N04	PAR	ES(0.4)	AIC	Yes	Niagara
7.	N05	PAR	ES(0.5)	AIC	Yes	Niagara
8.	N1N	PAR	Long term	(1)+	No	Niagara
9	N10	PAR	Long term	(1)	No	Niagara
10.	N11	PAR	ES(0.1)	(1)	Yes	Niagara
11.	N12	PAR	ES(0.2)	(1)	Yes	Niagara
12.	N13	PAR	ES(0.3)	(1)	Yes	Niagara
13.	N14	PAR	ES(0.4)	(1)	Yes	Niagara
14.	N15=(F05)	PAR	ES(0.5)	(1)	Yes	Niagara
15.	N0N	PAR	Long term	AIC	No	Erie
16.	N00	PAR	Long term	AIC	Yes	Erie
17.	N01	PAR	ES(0.1)**	AIC	Yes	Erie
18.	N02	PAR	ES(0.2)	AIC	Yes	Erie
19.	N03	PAR	ES(0.3)	AIC	Yes	Erie
20.	N04	PAR	ES(0.4)	AIC	Yes	Erie
21.	N05	PAR	ES(0.5)	AIC	Yes	Erie
22.	N1N	PAR	Long term	(1)+	No	Erie
23.	N10	PAR	Long term	(1)	No	Erie
24.	N11	PAR	ES(0.1)	(1)	Yes	Erie
25.	N12	PAR	ES(0.2)	(1)	Yes	Erie
26.	N13	PAR	ES(0.3)	(1)	Yes	Erie
27.	N14	PAR	ES(0.4)	(1)	Yes	Erie
28.	N15	PAR	ES(0.5)	(1)	Yes	Erie
29.	SPEI	Spectral	Long term		Yes	Erie
30.	SPEN	Spectral	Long term		No	Erie
31.	ROUT	Old Routing				
32.	NEWR	New Routing				
33.	F15	PAR	Rund of 15	AIC	Yes	Niagara

* For the spectral model all the parameters were updated during the validation period. For the PAR model only the monthly mean were updated.

** ES(α) denote exponential smoothing with parameter α.

\+ (1) the order of the model is set to one lag for each month

TABLE 3

Best Model for Validation Period 61(1) to 84(12)*

MONTH	YEAR					
	1	2	3	4	5	6
1	NON	N05	N05	N05	N05	N05
2	NE0N	N05	N05	N05	N05	N05
3	NE1N	N05	N05	N05	N05	NE05
4	NE10	N05	N05	NE05	NE05	NE05
5	ROUT	N05	N05	N05	NE05	NE05
6	ROUT	N05	N05	N05	N05	NE05
7	NON	N05	N05	N05	N05	N05
8	NO2	N05	N05	N05	N05	NE02
9	NO3	N05	N05	N05	N05	NE03
10	N14	N05	N05	N05	N05	N05
11	N14	N05	N05	N05	NE04	NE02
12	ROUT	N15	N05	N05	NE02	NE02

* This competition does not included the Models NEWR and F15.

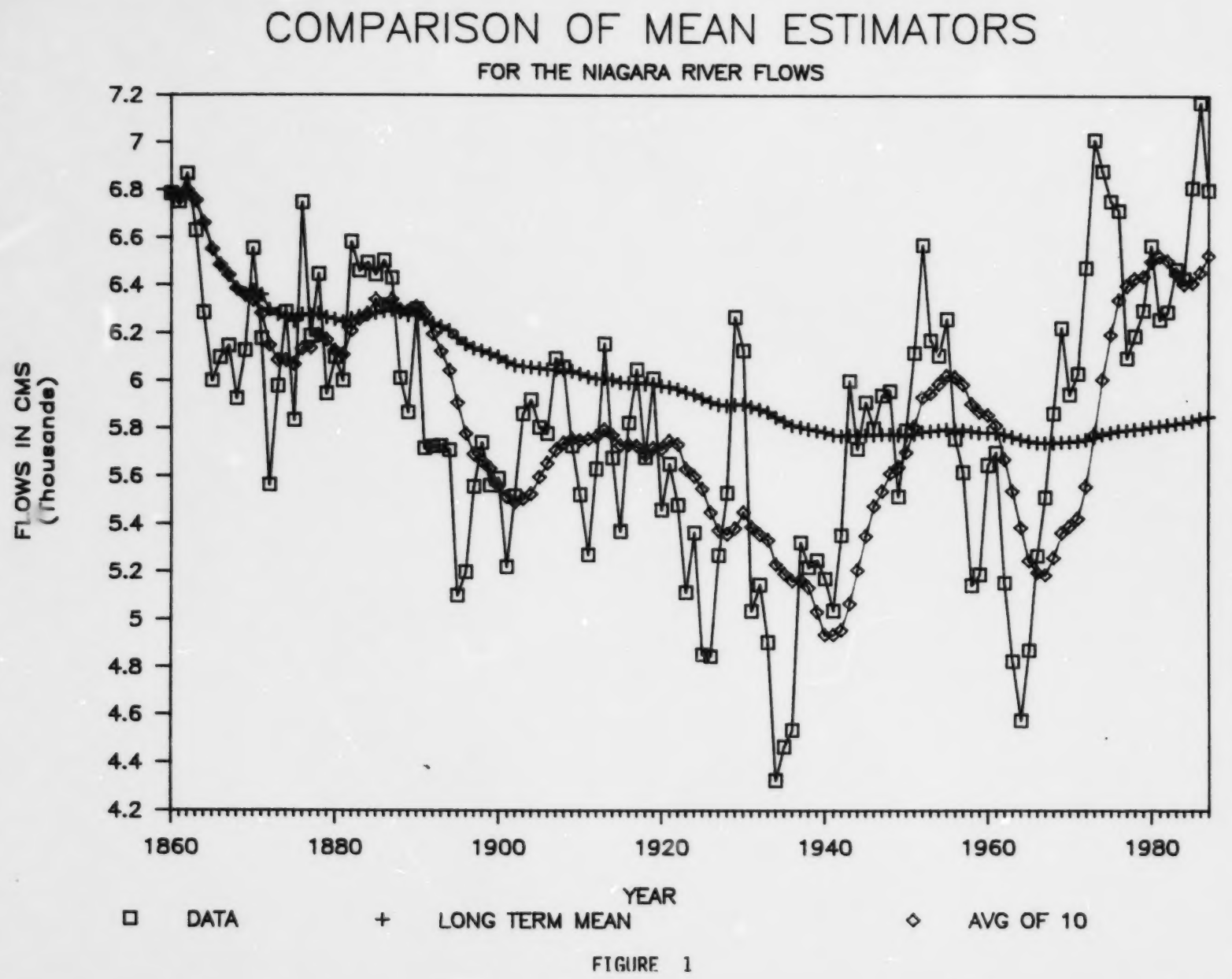
COMPARISON OF MEAN ESTIMATORS
FOR THE NIAGARA RIVER FLOWS
FLOWS IN CMS
(Thousands)
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
1860
1880
1900
1920
1940
1960
1980
YEAR
DATA
LONG TERM MEAN
AVG OF 10

FIGURE 1

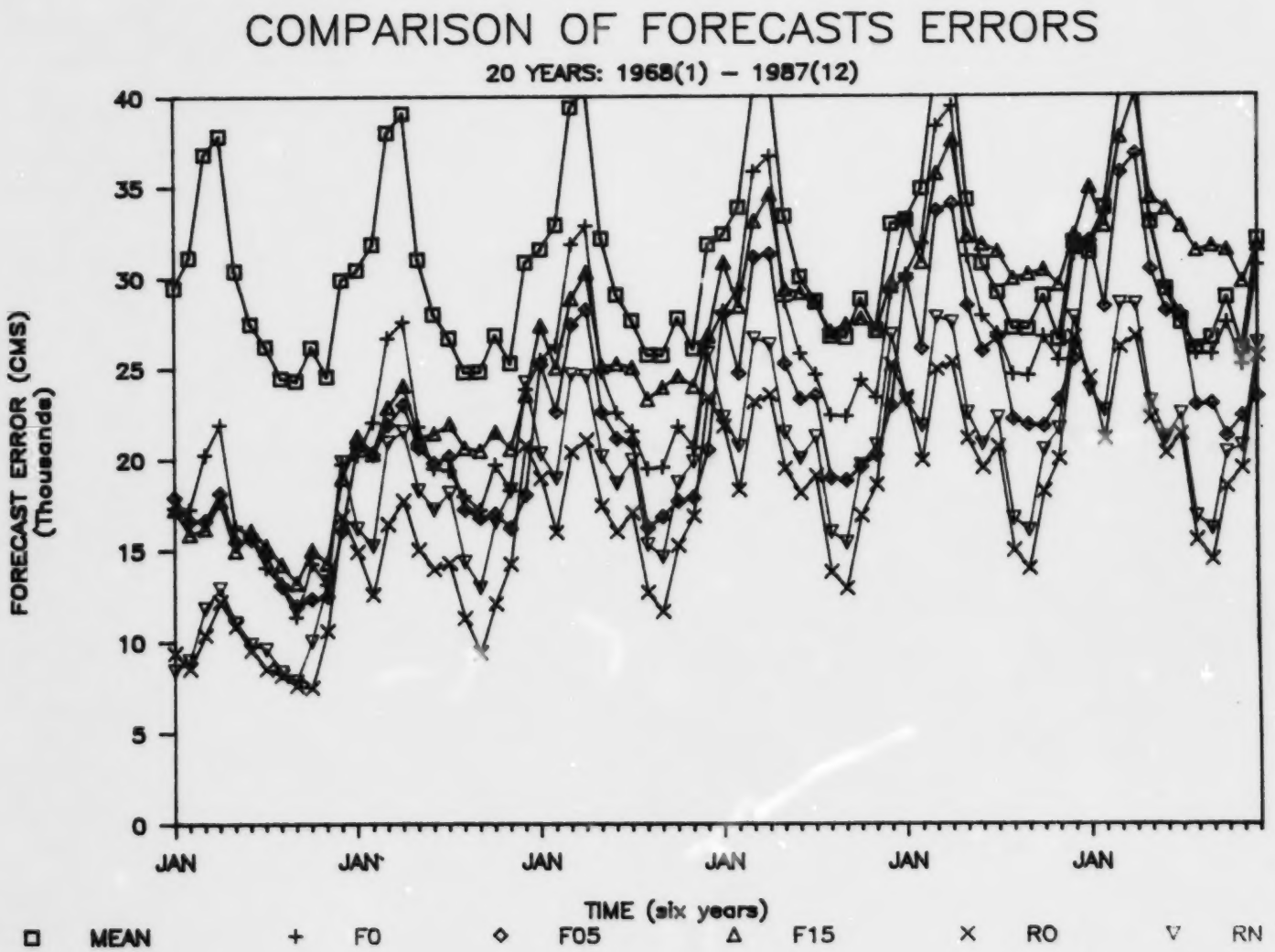
COMPARISON OF FORECASTS ERRORS
20 YEARS: 1968(1) – 1987(12)
FORECAST ERROR (CMS)
(Thousands)
40
35
30
25
20
15
10
5
0
JAN
JAN
JAN
JAN
JAN
JAN
TIME (six years)
MEAN
F0
F05
F15
RO
RN

FIGURE 2

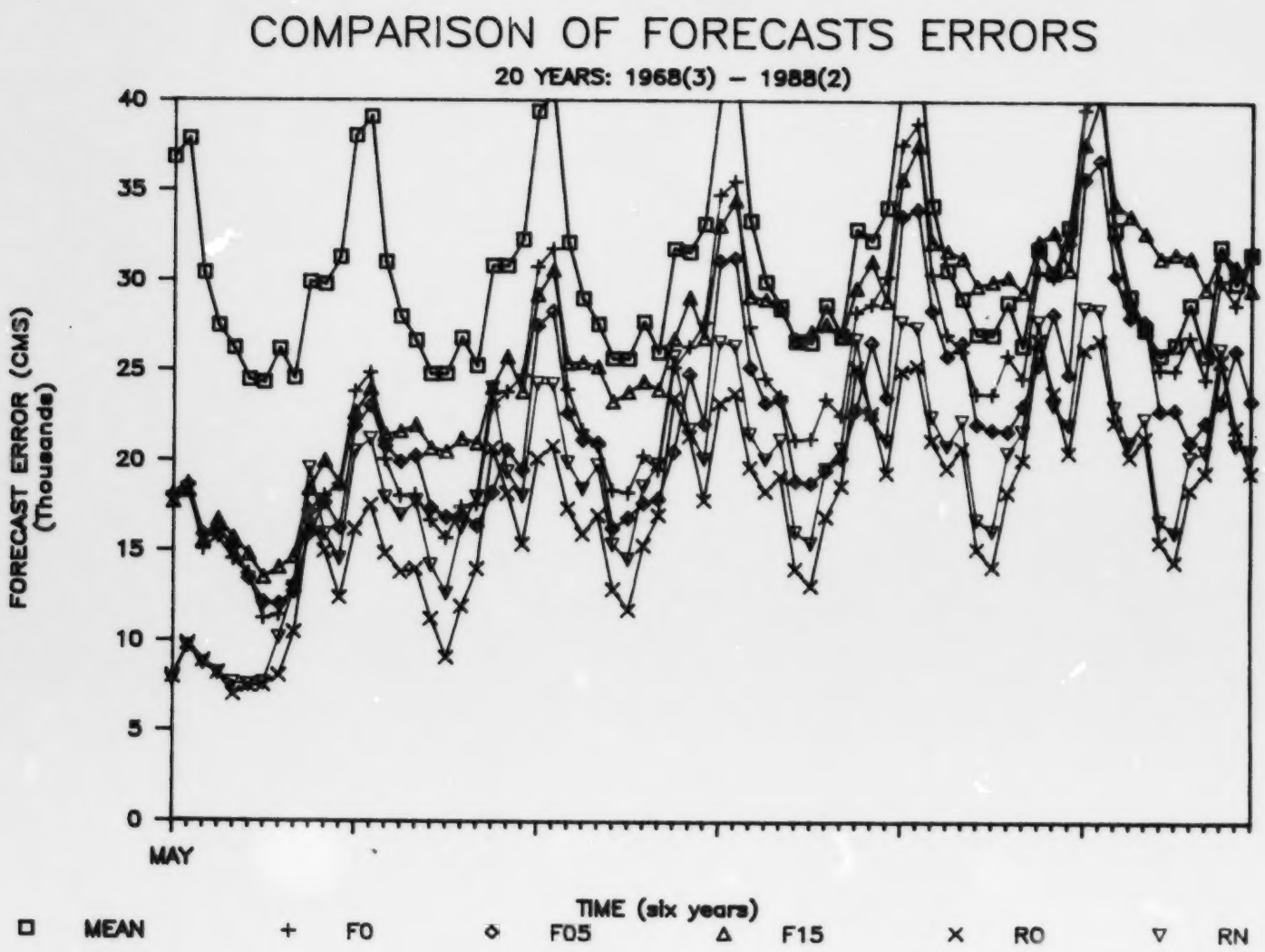
COMPARISON OF FORECASTS ERRORS
20 YEARS: 1968(3) – 1988(2)
FORECAST ERROR (CMS)
(Thousands)
40
35
30
25
20
15
10
5
0
MAY
TIME (six years)
MEAN
F0
F05
F15
RO
RN

FIGURE 3

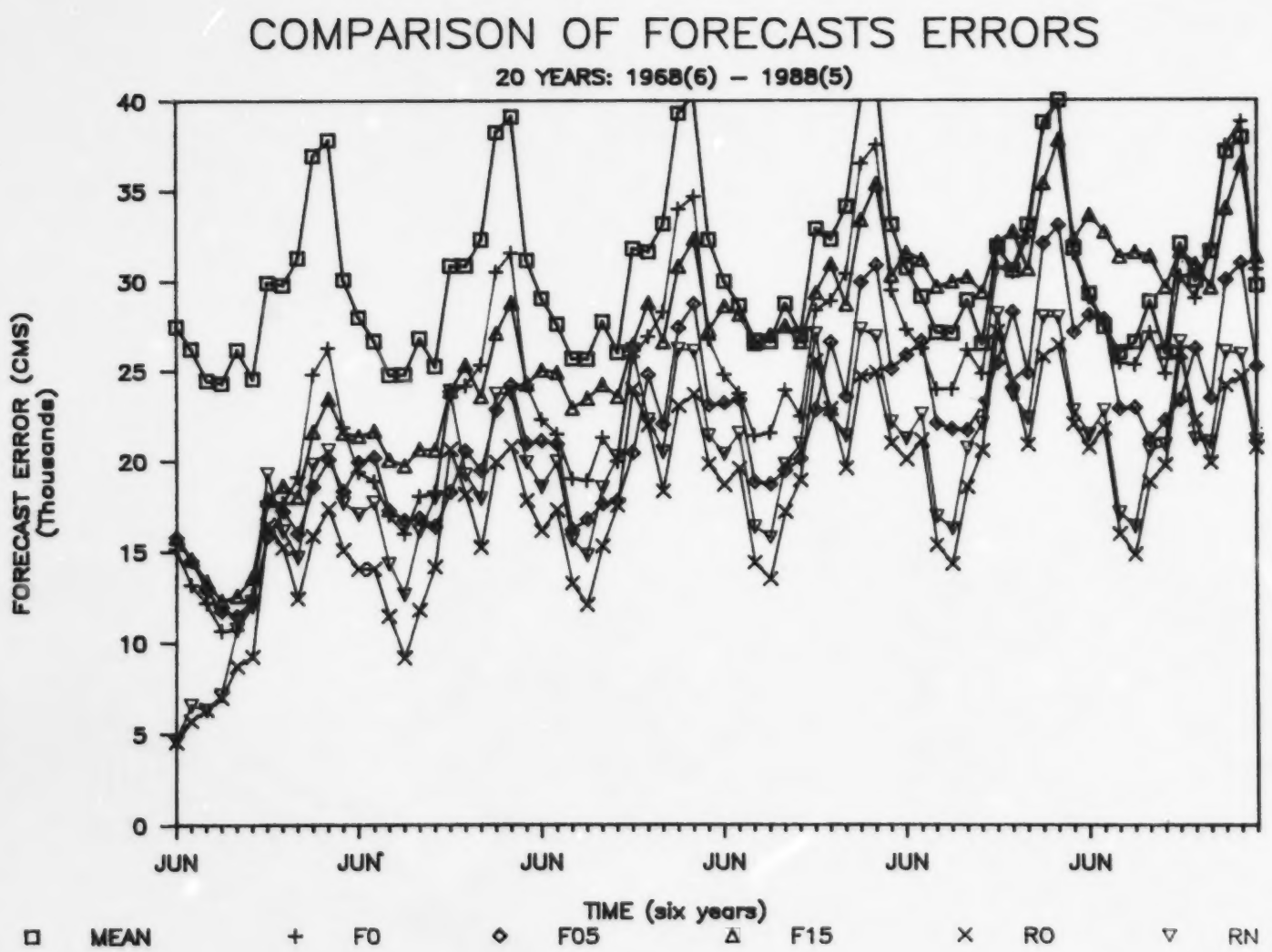
COMPARISON OF FORECASTS ERRORS
20 YEARS: 1968(6) – 1988(5)
FORECAST ERROR (CMS)
(Thousands)
40
35
30
25
20
15
10
5
0
JUN
JUN
JUN
JUN
JUN
JUN
TIME (six years)
MEAN
F0
F05
F15
RO
RN

FIGURE 4

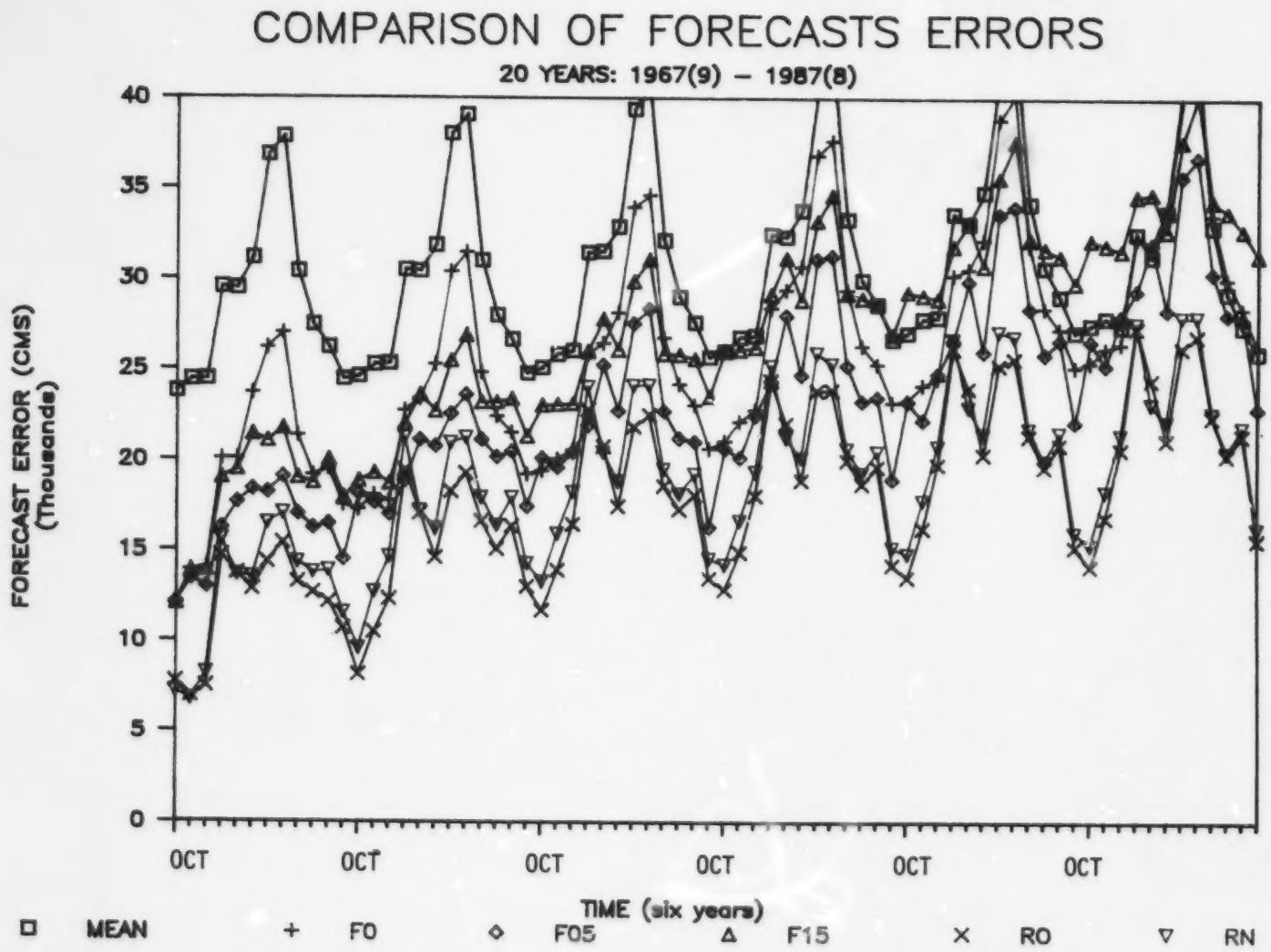
COMPARISON OF FORECASTS ERRORS
20 YEARS: 1967(9) – 1987(8)
FORECAST ERROR (CMS)
(Thousands)
40
35
30
25
20
15
10
5
0
OCT
OCT
OCT
OCT
OCT
OCT
TIME (six years)
MEAN
F0
F05
F15
RO
RN

FIGURE 5

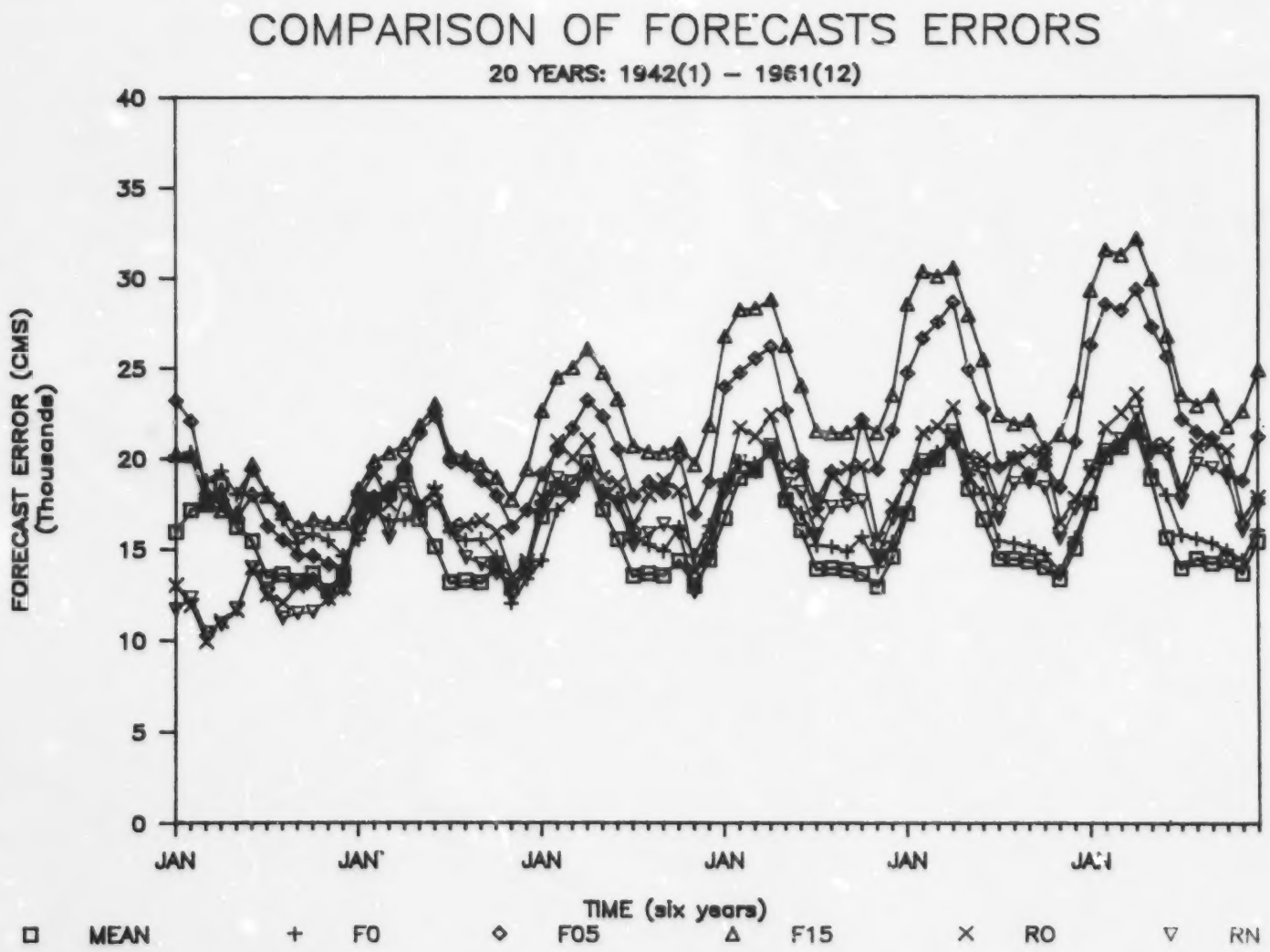
COMPARISON OF FORECASTS ERRORS
20 YEARS: 1942(1) – 1961(12)
FORECAST ERROR (CMS)
(Thousands)
40
35
30
25
20
15
10
5
0
JAN
JAN
JAN
JAN
JAN
JAN
TIME (six years)
MEAN
F0
F05
F15
RO
RN

FIGURE 6

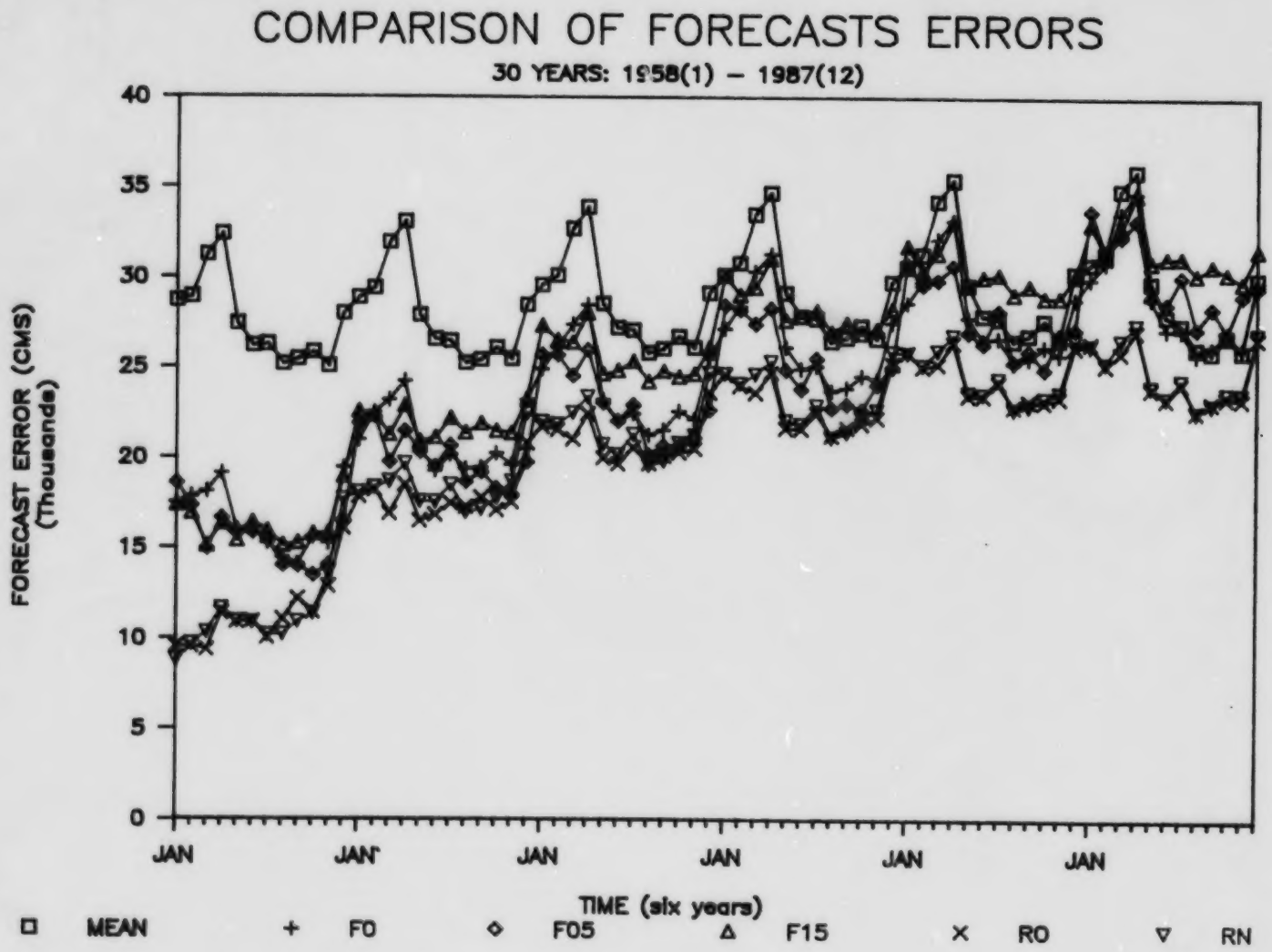
COMPARISON OF FORECASTS ERRORS
30 YEARS: 1958(1) – 1987(12)
FORECAST ERROR (CMS)
(Thousands)
40
35
30
25
20
15
10
5
0
JAN
JAN
JAN
JAN
JAN
JAN
TIME (six years)
MEAN
F0
F05
F15
RO
RN

FIGURE 7

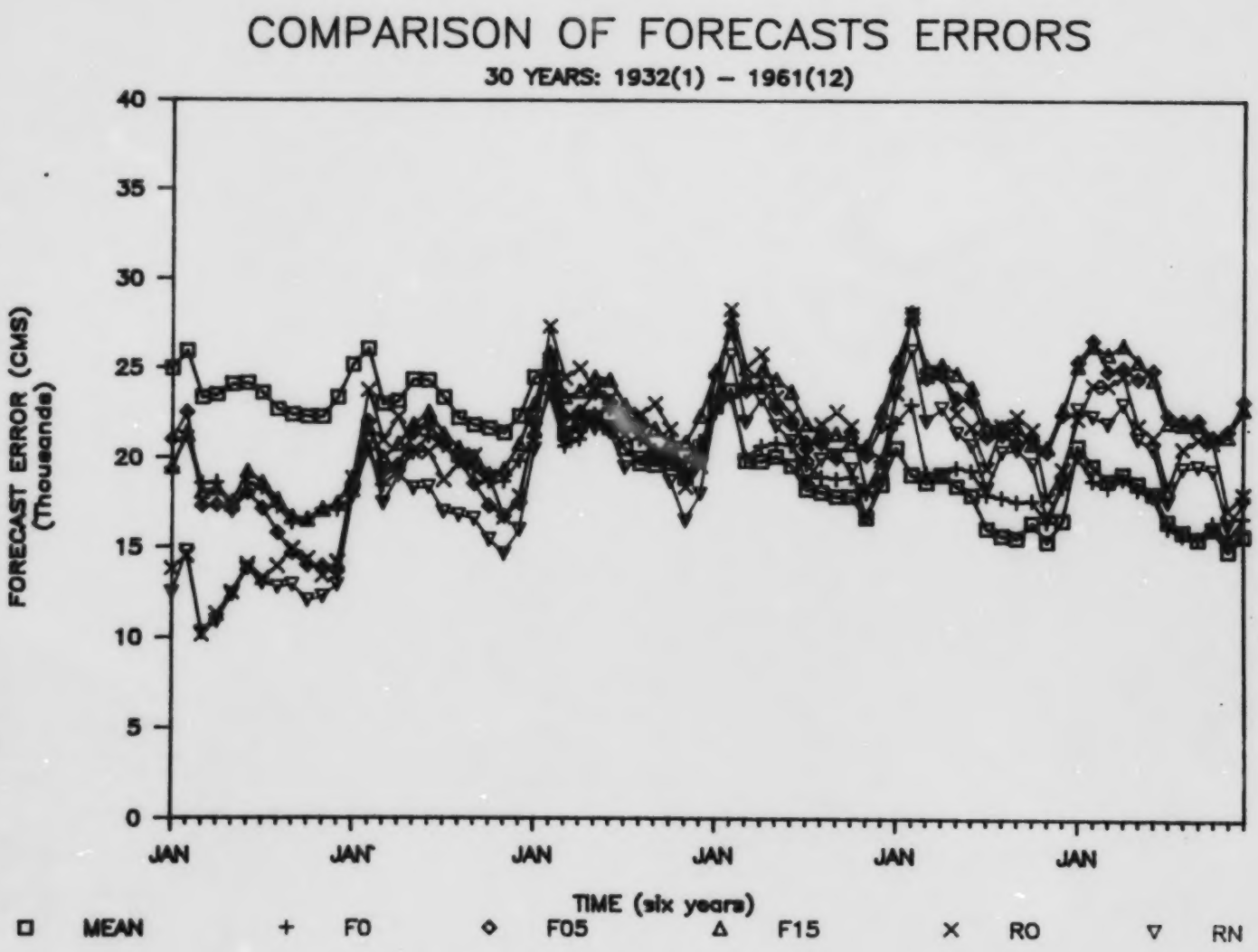
COMPARISON OF FORECASTS ERRORS
30 YEARS: 1932(1) – 1961(12)
FORECAST ERROR (CMS)
(Thousands)
40
35
30
25
20
15
10
5
0
JAN
JAN
JAN
JAN
JAN
JAN
TIME (six years)
MEAN
F0
F05
F15
RO
RN

FIGURE 8

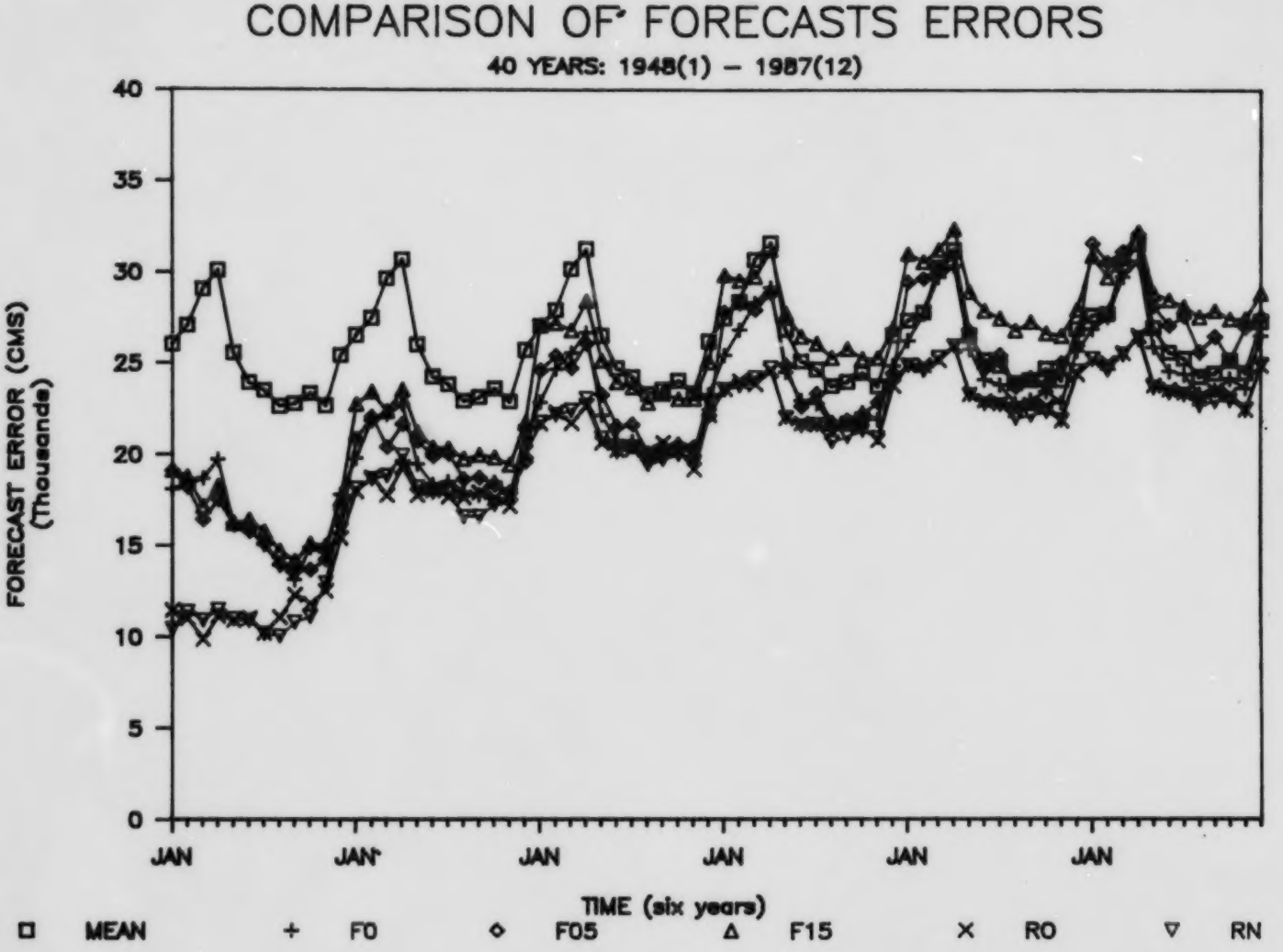
COMPARISON OF FORECASTS ERRORS
40 YEARS: 1948(1) – 1987(12)
FORECAST ERROR (CMS)
(Thousands)
40
35
30
25
20
15
10
5
0
JAN
JAN
JAN
JAN
JAN
JAN
TIME (six years)
MEAN
F0
F05
F15
RO
RN

FIGURE 9

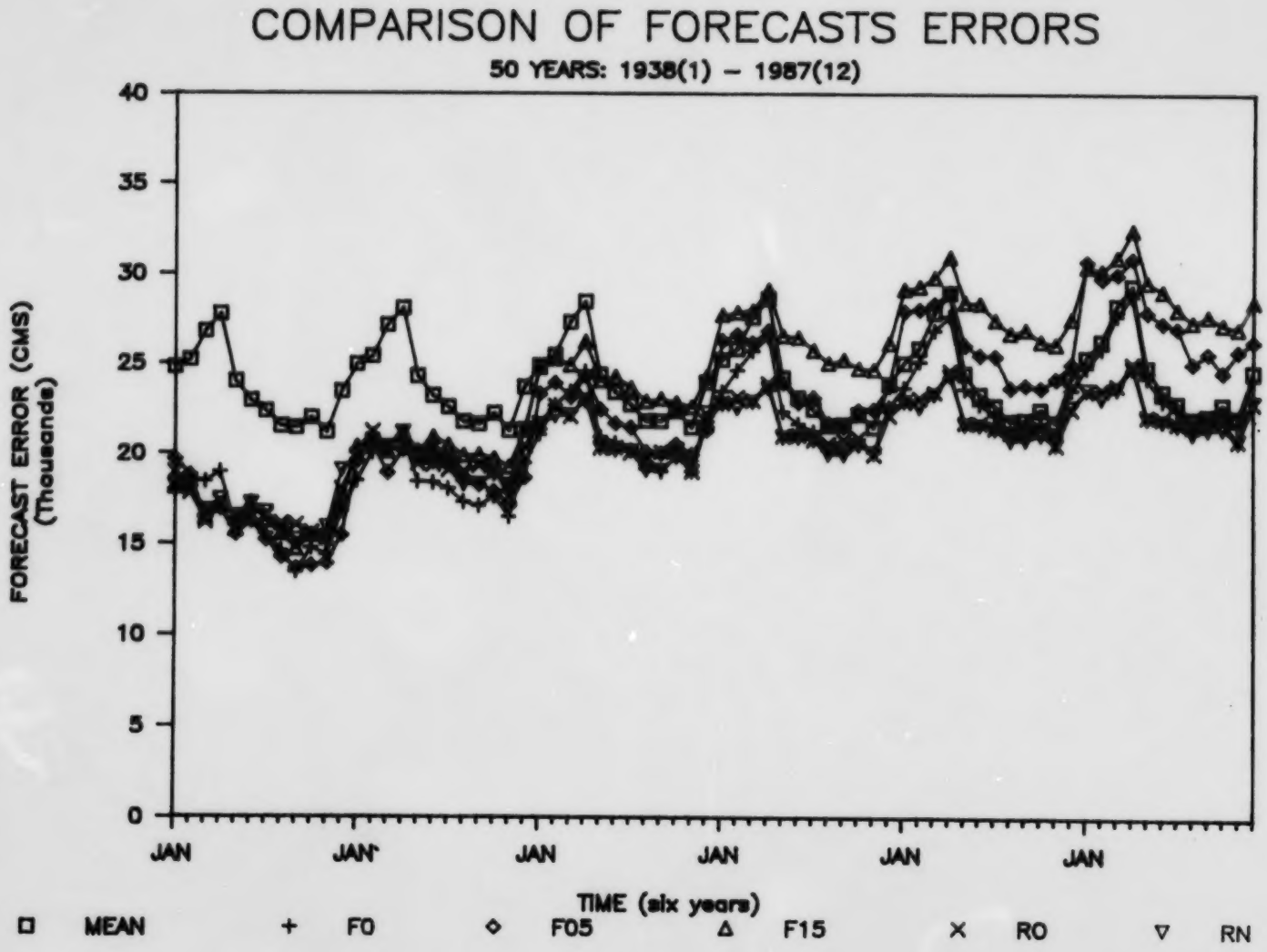
COMPARISON OF FORECASTS ERRORS
50 YEARS: 1938(1) – 1987(12)
FORECAST ERROR (CMS)
(Thousands)
40
35
30
25
20
15
10
5
0
JAN
JAN
JAN
JAN
JAN
JAN
TIME (six years)
MEAN
F0
F05
F15
RO
RN

FIGURE 10

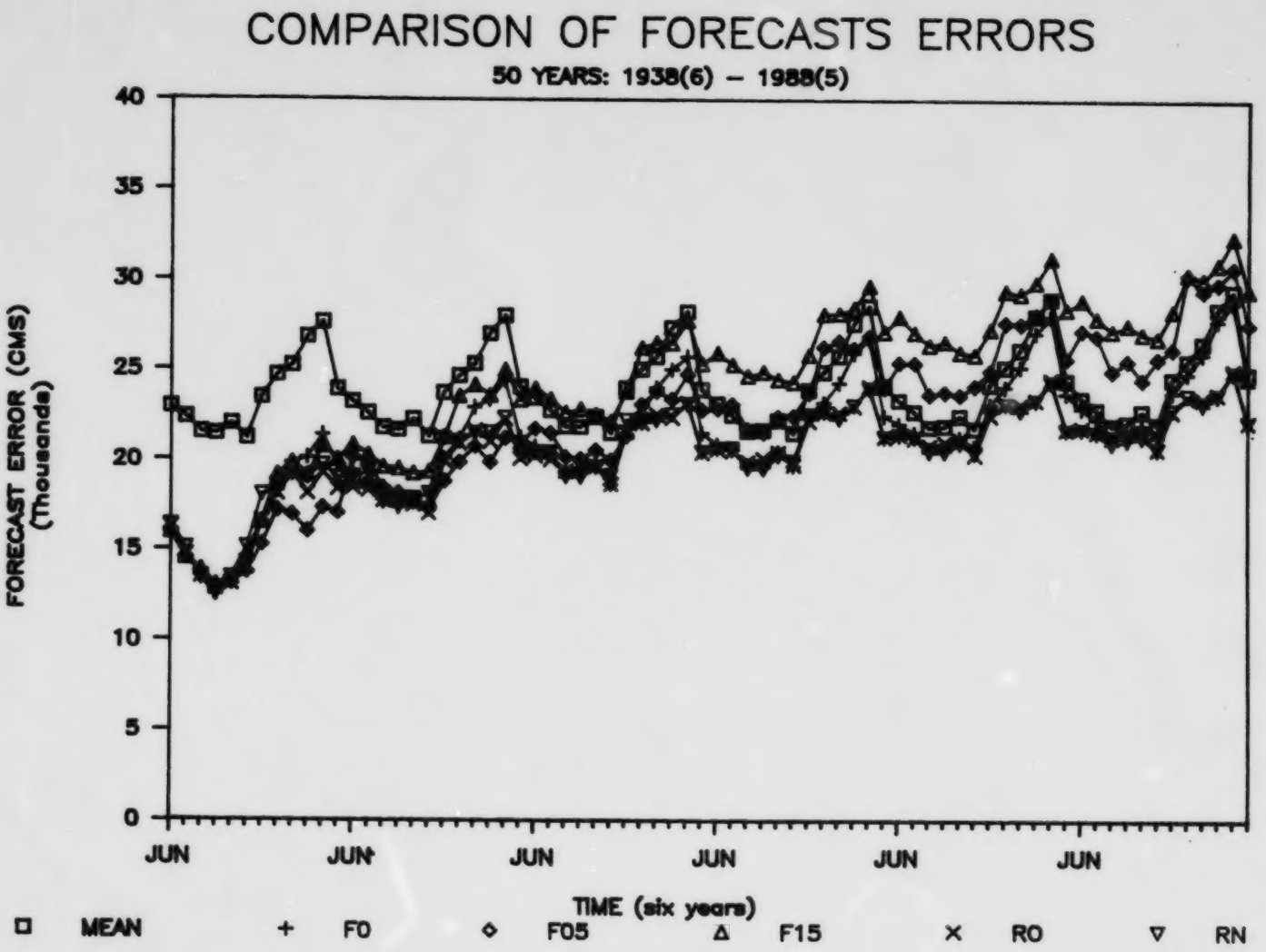
COMPARISON OF FORECASTS ERRORS
50 YEARS: 1938(6) – 1988(5)
FORECAST ERROR (CMS)
(Thousands)
40
35
30
25
20
15
10
5
0
JUN
JUN
JUN
JUN
JUN
JUN
TIME (six years)
MEAN
F0
F05
F15
RO
RN

FIGURE 11

APPENDIX A

Comparison of Mean Estimates

Section 2.4 of the report introduced several estimators can be used to estimate the mean of the Niagara River flows. In particular, the section introduced the exponential smoothing and run-averages of the last k observations. These estimators were introduced to remove from the data possible non-stationarities due to the fluctuation between wet and dry periods. The objective of this Appendix is to illustrate the similarities and differences between the estimators. Three plots were prepared for this purpose:

(i) A plot that compares the exponential smoothing estimators with different parameters (Figure A1). The parameters are 0.1 and 0.5. It can be seen that for large values of α, the estimates follow closer the plot of the data.

(ii) A plot that compares run-average estimators obtained with different number of observations (Figure A2). The number of observations are 10 and 20. As can be seen, the plot of the means is smoother as the number of points included in the calculation of the averages increases.

(iii) A plot that compares the exponential smoothing estimator with the run-average estimator (Figure A3). The parameter of the exponential smoothing was selected to give the last observation the same weight in both estimators. These were 0.1 and 10 respectively. As can be seen, the plot of the exponential smoothing values is smoother than the plot of the run-averages.

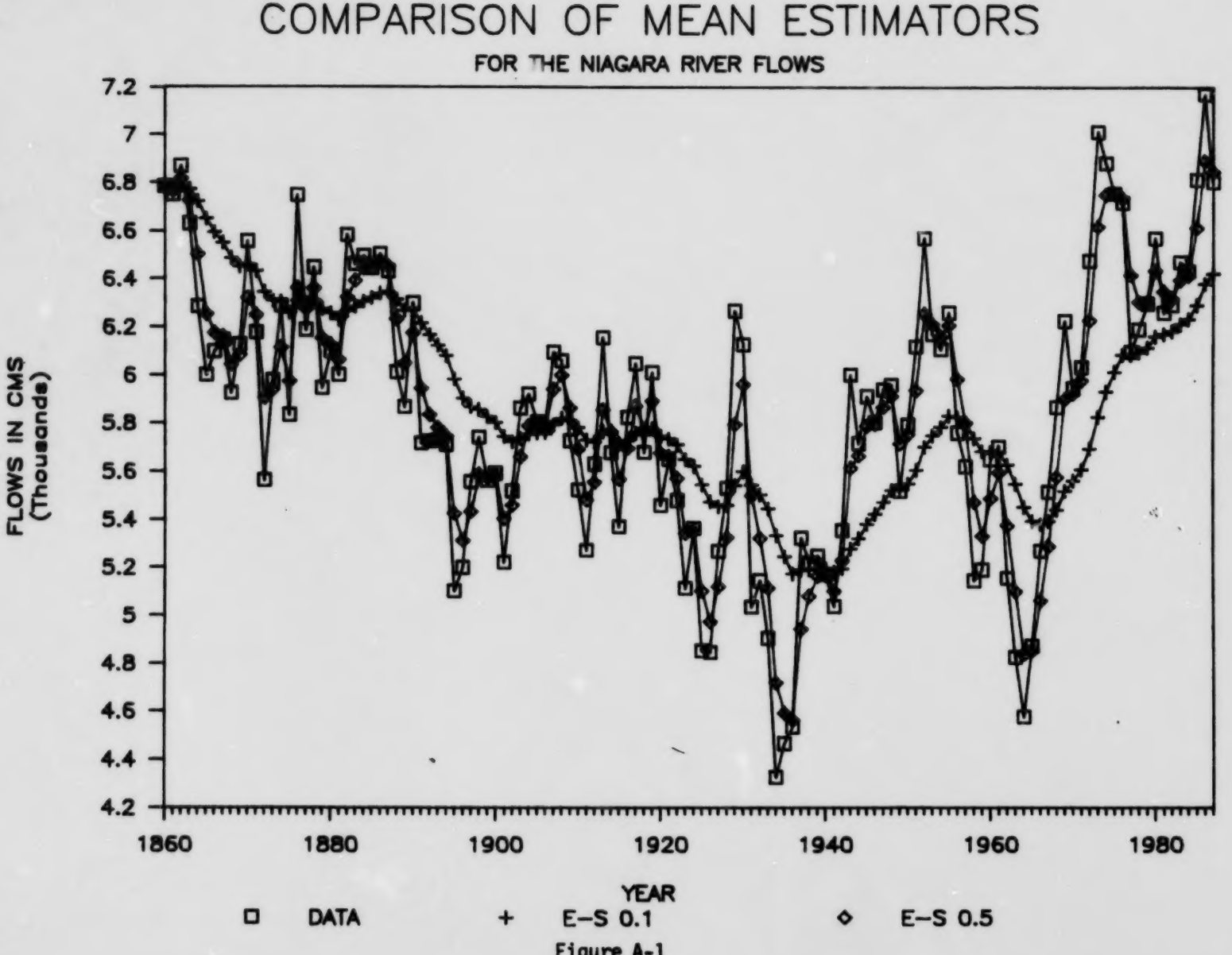
COMPARISON OF MEAN ESTIMATORS
FOR THE NIAGARA RIVER FLOWS
FLOWS IN CMS
(Thousands)
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
1860
1880
1900
1920
1940
1960
1980
YEAR
DATA
E-S 0.1
E-S 0.5

Figure A-1

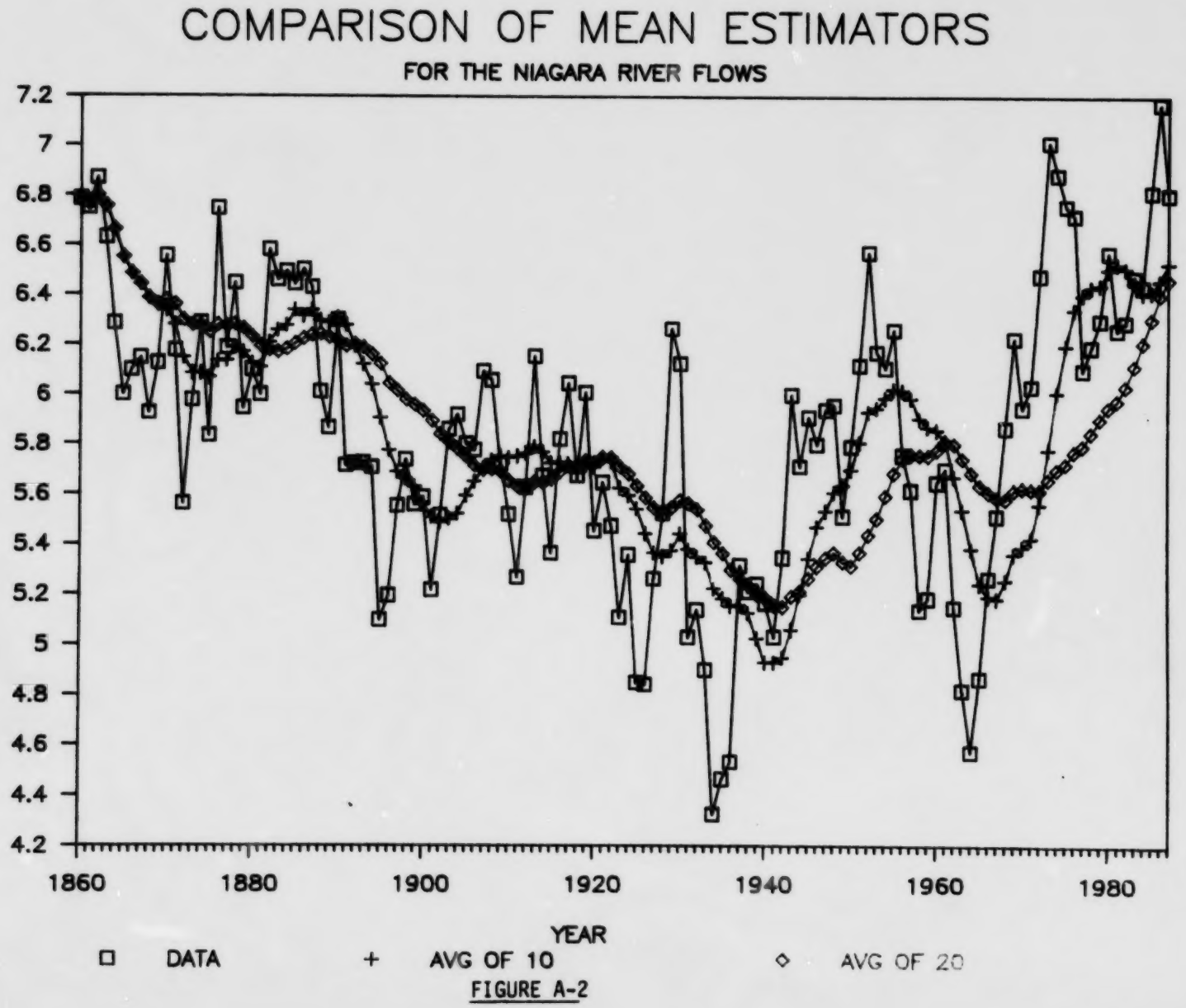
COMPARISON OF MEAN ESTIMATORS
FOR THE NIAGARA RIVER FLOWS
FLOWS IN CMS
(Thousands)
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
1860
1880
1900
1920
1940
1960
1980
YEAR
DATA
AVG OF 10
AVG OF 20

FIGURE A-2

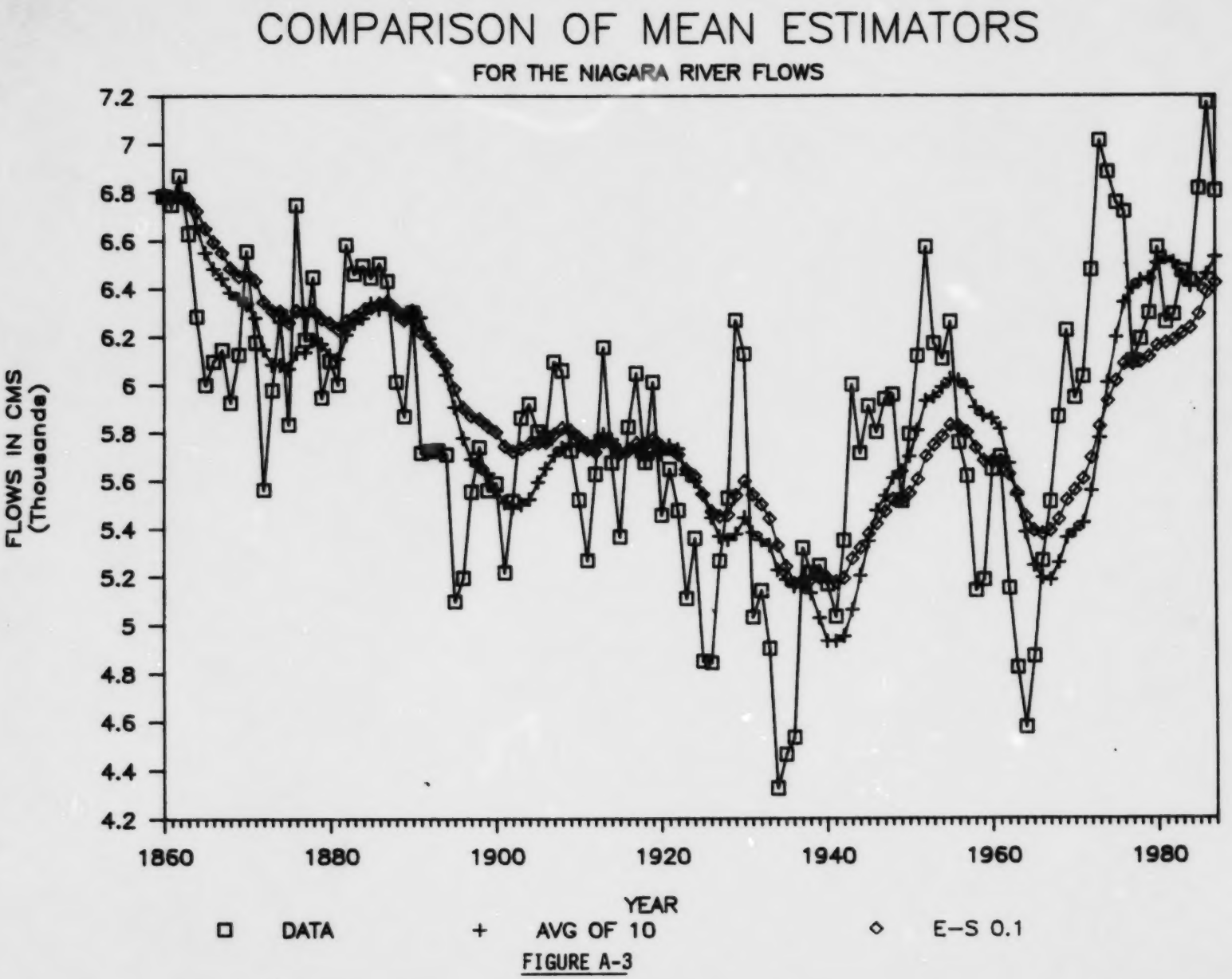
COMPARISON OF MEAN ESTIMATORS
FOR THE NIAGARA RIVER FLOWS
FLOWS IN CMS
(Thousands)
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
1860
1880
1900
1920
1940
1960
1980
YEAR
DATA
AVG OF 10
E-S 0.1

FIGURE A-3

APPENDIX B

Complete Results for Validation Period 1961 to 1984

This Appendix presents the results of the forecast competition obtained for the validation period 1961 to 1984. Thirty one (31) models were included in this competition: all the models listed in Table 4.1 except the NEWR and the F15 models. During this period, the river flows started below the long term mean, drop a little and then rise above the long term mean and remained there for the majority of the validation period.

Tables B1 to B31 list the root mean square errors (RMSE) for each model. For the periodic autoregressive model, the Tables also gives the order of the model fitted to the data using data from 1860 to 1960. For the spectral and the routing model, the Table also lists the RMSE of the forecasts for the Lake Erie evaluations. In addition, for the spectral model, the Tables list the cycle (in years) of the frequencies included in the model. Table B33 presents the rank obtained by each model at each period.

```
TYPE NON.OUT

 YEARS USED TO ESTIMATE THE PARAMETERS = 101
 YEARS USED TO ESTIMATE THE STD. DEV   =  24
1

     NIAGARA RIVER FLOWS (1860-1984)


 MEANS ARE NOT UPDATED

ORDER OF THE PERIODIC AR  1  1  3  1  1  6  6  2 10  1  1  2
```

PERIOD	MEAN
1	5538.
2	5362.
3	5542.
4	5801.
5	6091.
6	6144.
7	6045.
8	5932.
9	5811.
10	5712.
11	5722.
12	5713.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	267.3616	429.5496	542.0298	618.3646	614.5219	626.4136
2	347.6420	492.7675	597.1665	664.2080	681.9354	721.1877
3	384.3571	541.7781	651.7989	735.0878	787.8851	833.8179
4	402.8185	579.5377	690.6404	769.9153	825.4066	865.1979
5	314.1462	448.2549	544.2180	609.0217	653.3406	676.6782
6	283.4563	422.2315	498.3077	555.3166	581.9230	601.8588
7	300.7898	437.7318	508.2750	550.1892	559.0081	566.4191
8	301.2670	437.1015	507.0927	545.0790	551.1608	551.9392
9	365.5685	464.0472	534.1785	550.7935	557.8746	567.0112
10	363.2961	449.0450	515.7941	521.4389	519.6686	539.9321
11	385.1858	466.6102	517.9129	535.9474	514.4059	535.2803
12	441.8438	518.4758	583.5275	606.9130	584.9933	603.3713

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24
1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.000

ORDER OF THE PERIODIC AR 1 1 3 1 1 6 6 2 10 1 1 2

PERIOD	MEAN
1	5571.
2	5425.
3	5623.
4	5882.
5	6146.
6	6181.
7	6071.
8	5960.
9	5840.
10	5743.
11	5746.
12	5757.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	268.4933	430.6807	542.8889	619.3588	617.2075	631.7393
2	343.0528	484.5769	587.8238	654.1432	671.7773	711.6038
3	369.6476	523.9030	633.0798	715.6403	767.7157	813.3281
4	388.3047	563.0016	673.3219	751.8338	806.7679	846.3458
5	310.7148	441.9137	536.7454	600.8135	644.9217	668.6584
6	284.2834	421.7583	497.0541	553.9777	581.3263	602.7408
7	301.9959	439.2344	509.6403	552.0681	562.6103	572.6687
8	302.6166	438.2774	508.0146	546.4197	554.1316	557.6700
9	367.0932	465.2550	535.0404	552.1148	560.8679	572.4717
10	364.6373	449.8070	516.1658	522.2819	522.3396	544.4729
11	386.9646	468.3553	519.7517	538.7676	520.1111	543.2013
12	441.1382	516.4036	580.6251	603.7598	582.9290	602.7297

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24
1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.100

ORDER OF THE PERIODIC AR 1 1 3 1 1 6 6 2 10 1 1 2

PERIOD	MEAN
1	5955.
2	5899.
3	6176.
4	6446.
5	6575.
6	6550.
7	6401.
8	6327.
9	6210.
10	6100.
11	6094.
12	6178.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	274.9038	407.4995	502.6614	568.7338	565.3945	589.0911
2	324.8265	424.5515	506.7685	558.2446	567.9066	606.4922
3	309.1566	415.9542	504.7855	572.2272	612.2692	651.1917
4	318.5984	452.1687	543.1577	606.5446	651.0125	684.8210
5	297.8257	388.9648	462.3430	511.4330	547.4449	569.2421
6	284.5020	388.6393	443.0299	488.9082	512.9507	537.8749
7	305.7192	418.7606	472.8262	507.3965	520.0415	539.9119
8	301.4699	406.9663	458.2480	487.6902	495.7358	508.8079
9	359.2237	434.4358	485.5722	490.6718	500.0511	519.5881
10	356.4469	417.8896	466.5422	460.4867	461.8084	488.3493
11	381.3440	441.5430	476.9879	489.0463	476.3219	504.8013
12	424.6352	473.9699	519.5395	529.6163	505.7597	528.4070

YEARS USED TO ESTIMATE THE PARAMETERS = 101

YEARS USED TO ESTIMATE THE STD. DEV = 24

1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.200

ORDER OF THE PERIODIC AR 1 1 3 1 1 6 6 2 10 1 1 2

PERIOD	MEAN
1	6093.
2	6036.
3	6324.
4	6592.
5	6688.
6	6659.
7	6513.
8	6475.
9	6350.
10	6221.
11	6236.
12	6339.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	276.4536	379.8644	459.6951	516.5164	511.9037	540.9560
2	318.4351	395.3675	462.7409	504.5406	512.4756	549.6169
3	296.5592	373.7703	446.5708	502.5524	535.2512	570.6223
4	297.8262	402.1234	477.3980	523.5508	567.8647	599.5952
5	296.9536	360.5662	415.6635	453.2814	484.5937	506.9147
6	282.6970	357.3885	391.8807	428.7320	450.8532	477.7608
7	303.2442	390.3275	427.7521	455.1178	469.2903	494.3243
8	298.2826	373.5286	407.4913	427.6358	436.1776	455.0474
9	348.9097	401.2154	433.4494	426.9472	437.1038	460.3926
10	347.0029	385.9739	417.6476	400.0662	402.8733	428.7267
11	371.2607	409.4041	428.4396	433.3383	424.4841	450.8164
12	418.9901	447.5721	477.5186	477.6769	454.8791	476.8064

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24

1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.300

ORDER OF THE PERIODIC AR 1 1 3 1 1 6 6 2 10 1 1 2

PERIOD	MEAN
1	6117.
2	6070.
3	6354.
4	6608.
5	6690.
6	6654.
7	6526.
8	6505.
9	6370.
10	6226.
11	6270.
12	6387.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	277.1963	359.0125	428.1756	479.0300	475.2693	507.1413
2	314.3079	376.7976	434.5623	470.9274	480.3459	514.6263
3	292.8552	351.5458	413.4738	461.9391	490.7611	524.0032
4	287.5244	373.5151	438.1252	483.4186	518.9705	550.2553
5	298.8643	343.8667	385.0931	415.6162	445.1432	468.8114
6	282.2109	335.3946	354.2674	385.9780	408.2808	435.9960
7	301.0463	367.7317	392.1497	415.6066	432.3141	459.5158
8	298.8119	352.4011	373.1177	388.7824	399.9145	422.1498
9	344.5266	379.9912	397.7938	384.7541	397.5801	421.7463
10	342.9504	365.7519	385.0920	360.9744	366.9891	388.6758
11	366.3116	387.7020	394.7079	395.8096	391.4705	411.1635
12	420.6032	434.7881	453.7940	448.2616	429.1768	447.5536

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24
1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.400

ORDER OF THE PERIODIC AR 1 1 3 1 1 6 6 2 10 1 1 2

PERIOD	MEAN
1	6122.
2	6097.
3	6378.
4	6618.
5	6685.
6	6636.
7	6530.
8	6512.
9	6370.
10	6216.
11	6286.
12	6411.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	278.4729	344.0809	405.4599	452.1546	449.9870	482.3212
2	311.7920	363.3096	414.0611	447.0189	458.7295	488.5865
3	292.2153	337.8686	391.8011	434.9093	461.5087	492.8633
4	281.3677	355.0182	411.8483	452.8489	487.2128	518.2711
5	303.0221	334.4716	384.3434	390.5516	419.4676	444.0417
6	283.8593	321.0191	327.2136	356.1891	379.2837	406.4110
7	301.0679	351.4063	365.3089	386.8894	405.9696	432.9337
8	302.0554	339.4258	349.9679	383.6449	377.5388	400.6117
9	344.5291	367.0856	373.4241	357.3203	372.6592	395.0575
10	343.0794	353.6936	363.7010	336.3315	345.2413	360.2975
11	366.2143	374.3224	372.2095	371.2650	370.5629	380.9432
12	426.6497	429.6859	440.2243	431.0424	416.1744	428.1920

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24

1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.500

ORDER OF THE PERIODIC AR 1 1 3 1 1 6 6 2 10 1 1 2

PERIOD	MEAN
1	6122.
2	6127.
3	6403.
4	6638.
5	6687.
6	6624.
7	6537.
8	6516.
9	6371.
10	6210.
11	6297.
12	6424.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	280.2671	333.9954	389.7831	433.5867	433.3169	464.4581
2	310.3160	353.0409	398.5337	429.3588	443.4674	467.9892
3	293.3507	329.8461	377.9293	417.2565	442.7061	472.2545
4	277.8282	343.1907	394.3118	432.8751	466.8966	497.6734
5	309.0108	330.4021	350.7950	374.7734	403.4703	428.3438
6	287.1725	312.5725	308.6455	336.5289	360.4025	386.0626
7	303.0988	340.3546	345.8285	366.8878	387.7390	413.0417
8	307.2627	332.0487	334.6995	347.8947	363.9330	386.1505
9	347.6026	359.9590	357.0530	340.3415	357.1219	376.2272
10	346.4918	347.5585	350.3604	321.9482	332.5851	340.1362
11	370.4360	367.8437	358.8681	356.8212	358.4943	358.8265
12	436.4884	430.4446	434.1404	422.4919	411.2870	415.6614

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24

1

NIAGARA RIVER FLOWS (1860-1984)

MEANS ARE NOT UPDATED

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

PERIOD	MEAN
1	5538.
2	5362.
3	5542.
4	5801.
5	6091.
6	6144.
7	6045.
8	5932.
9	5811.
10	5712.
11	5722.
12	5713.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	267.3616	444.1160	590.9095	675.4460	665.1341	664.3436
2	347.6420	505.6754	641.8823	717.1483	728.5198	757.4410
3	399.9942	572.0389	706.6205	793.0412	837.2665	871.9117
4	423.8535	611.0271	745.6273	827.2885	874.2891	902.3651
5	327.3216	477.6271	597.1455	664.7406	700.5415	711.7154
6	301.9377	456.5557	554.5050	612.7896	629.6508	636.9022
7	324.4740	475.2816	585.1108	607.5829	606.2068	600.4095
8	325.1921	472.4742	580.6592	599.3353	595.8323	583.9882
9	371.4142	507.0097	591.6774	607.8108	603.7664	599.6563
10	388.0946	487.0469	567.6077	573.6032	561.7040	570.2911
11	389.9063	503.1771	568.6204	586.2888	555.1633	564.7687
12	449.3109	554.3786	630.6425	652.6389	621.1736	629.2039

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24

1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.000

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

PERIOD	MEAN
1	5571.
2	5425.
3	5623.
4	5882.
5	6146.
6	6181.
7	6071.
8	5960.
9	5840.
10	5743.
11	5746.
12	5757.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	268.4933	445.1890	591.5443	676.1678	667.5610	669.6204
2	343.0528	497.3410	632.2300	706.7837	718.1335	747.7957
3	384.5309	554.0087	687.7582	773.4663	816.9896	851.3842
4	408.9100	594.3933	728.1886	809.0903	855.5518	883.4811
5	323.3371	471.0334	589.3639	656.2540	691.9099	703.6106
6	302.5298	455.8335	552.9142	611.1182	628.8022	637.7205
7	325.9171	476.6823	586.2522	609.1882	609.5798	606.6359
8	326.6083	473.5044	561.3289	600.3870	598.5616	589.6706
9	372.9276	508.0034	592.2361	608.7896	606.4856	605.0671
10	369.3986	487.5277	567.6196	574.0521	564.0500	574.7626
11	391.6978	504.7866	570.1989	588.7826	560.5538	572.6572
12	448.4123	551.7961	627.2148	649.0187	618.7411	628.4365

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24

1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.100

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

PERIOD	MEAN
1	5955.
2	5899.
3	6176.
4	6446.
5	6575.
6	6550.
7	6401.
8	6327.
9	6210.
10	6100.
11	6094.
12	6178.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	274.9038	419.6245	544.0922	617.2512	607.8337	621.3252
2	324.8265	434.5992	543.5237	602.3688	606.4021	637.1444
3	316.0991	440.2101	550.8813	621.4918	653.9515	683.4781
4	332.4535	478.4814	590.2466	655.9244	692.8238	716.6010
5	304.6615	412.4218	506.4483	558.3728	587.0358	598.6501
6	296.7662	416.3598	490.0789	537.3366	552.9095	567.5760
7	324.8728	450.0248	520.8762	555.8989	559.4810	568.7588
8	318.6486	435.6299	503.4575	533.0725	532.6762	535.5524
9	363.3351	468.3469	532.4578	537.5461	537.3531	546.5430
10	359.4271	446.4639	507.3788	502.1125	494.8501	513.0167
11	384.5321	469.5334	517.2034	529.1348	507.9908	528.7969
12	428.5038	498.7120	554.3596	563.9803	532.0980	547.7863

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24
1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.200

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

PERIOD	MEAN
1	6093.
2	6036.
3	6324.
4	6592.
5	6688.
6	6659.
7	6513.
8	6475.
9	6350.
10	6221.
11	6236.
12	6339.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	276.4536	389.8157	494.6491	557.7512	547.5403	568.6108
2	318.4351	403.4953	493.4592	541.6866	544.5510	576.1431
3	299.8040	393.1795	485.0381	544.1230	570.2625	598.1444
4	307.5705	424.0889	517.5883	571.9037	603.6349	627.0286
5	300.8449	379.3567	452.4100	492.7681	517.8472	531.8375
6	289.7608	379.4325	431.0753	469.4458	484.3041	503.1217
7	316.5807	415.6516	467.8822	495.8182	502.1382	518.9190
8	308.4413	395.8315	443.8397	464.9970	466.3066	477.2514
9	351.2845	426.4700	470.3723	464.4346	466.6820	482.3698
10	348.3139	405.8186	448.3328	431.9514	427.8358	448.4593
11	372.8155	428.8537	458.4641	463.7240	447.8901	469.9080
12	420.2458	463.1217	501.7364	501.9812	472.3074	490.6921

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24
1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.300

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

PERIOD	MEAN
1	6117.
2	6070.
3	6354.
4	6608.
5	6690.
6	6654.
7	6526.
8	6505.
9	6370.
10	6226.
11	6270.
12	6387.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	277.1963	367.3902	458.5312	515.1743	506.3213	532.0464
2	314.3079	383.6607	461.2128	503.3750	508.2845	538.8135
3	294.0422	367.6279	446.6027	498.1533	521.2781	548.5373
4	294.8837	392.5868	473.6521	521.0368	550.8396	575.1162
5	300.7066	359.3451	416.5703	449.7947	474.1010	490.9536
6	285.5112	353.2501	387.6920	421.1163	437.2616	458.6541
7	309.6697	388.5388	426.3524	450.5703	460.5732	481.4286
8	304.0870	389.9878	403.2497	420.1292	425.1824	441.4298
9	345.6490	398.6921	427.0390	414.9159	421.4687	440.3876
10	343.0912	379.0627	407.9999	385.2306	385.9770	405.0693
11	366.6427	400.4880	416.6192	418.5114	408.6505	426.7847
12	420.0800	443.6230	470.0205	464.8950	440.4222	457.6244

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24

1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.400

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

PERIOD	MEAN
1	6122.
2	6097.
3	6376.
4	6618.
5	6685.
6	6636.
7	6530.
8	6512.
9	6370.
10	6216.
11	6286.
12	6411.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	278.4729	351.2605	432.3345	484.5104	477.7556	505.4218
2	311.7920	369.2226	437.6635	475.9937	483.7629	511.2522
3	292.0375	351.4832	420.9192	467.1284	488.7826	515.3372
4	287.2129	372.0414	444.0197	487.0788	516.4218	541.4955
5	303.4104	347.4068	391.7081	420.6166	445.2729	464.2603
6	284.4488	335.6176	356.0570	386.9792	404.9666	427.1873
7	305.9292	368.5632	394.6982	417.2778	430.7677	452.9134
8	303.7904	353.3103	375.0765	390.1621	399.1115	417.7782
9	344.7127	380.5507	396.3311	381.3537	392.0807	411.1591
10	342.3604	361.8388	380.2533	354.2295	359.5530	374.0852
11	365.5914	381.5920	387.1910	387.4461	382.6986	393.6565
12	424.7570	433.1088	449.8443	441.3102	422.3502	435.1378

YEARS USED TO ESTIMATE THE PARAMETERS = 101
YEARS USED TO ESTIMATE THE STD. DEV = 24

1

NIAGARA RIVER FLOWS (1860-1984)

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.500

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

PERIOD	MEAN
1	6122.
2	6127.
3	6403.
4	6638.
5	6687.
6	6624.
7	6537.
8	6516.
9	6371.
10	6210.
11	6297.
12	6424.

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	280.2671	340.2737	414.0425	463.1423	458.7686	486.3876
2	310.3160	358.2144	419.7985	455.7292	466.4467	489.6284
3	292.2655	341.6389	404.0387	446.5023	467.6575	493.3011
4	282.7160	358.7678	424.0708	464.6934	494.3246	519.8695
5	308.3313	341.3464	374.8730	401.5907	428.9282	447.1727
6	285.8419	324.6527	333.8184	363.9195	383.6554	405.4813
7	304.9780	354.5329	371.2334	393.5775	409.8902	431.5432
8	306.3064	342.9466	355.6365	370.4638	382.6424	401.6757
9	347.0544	369.1294	374.5822	359.1643	372.9662	390.2306
10	345.1087	351.4835	361.5820	334.4576	343.1508	351.6724
11	389.0525	370.4555	367.8115	367.3718	366.4239	368.8535
12	433.4750	429.3091	438.0807	427.2947	413.2731	419.7973

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984
MEANS ARE NOT UPDATED

ORDER OF THE PERIODIC AR 1 2 5 1 2 4 1 2 2 3 1 4

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	353.4205	432.0912	567.4191	652.4124	644.9030	648.4979
2	283.5648	453.4054	602.7083	686.7057	705.7726	742.1612
3	270.6917	481.5029	648.2162	750.6382	806.9642	849.9734
4	341.0312	544.9553	698.1479	792.0275	848.6161	883.1054
5	308.6932	438.4029	581.9789	635.7206	678.6875	694.7387
6	322.6449	440.4679	530.9367	590.2538	610.9673	621.6991
7	366.4048	472.9318	550.6514	590.4827	590.9614	587.5798
8	362.0160	468.9264	546.1190	582.1074	580.0729	570.0405
9	394.4656	501.2078	577.8804	591.1367	589.3122	587.8083
10	387.4906	484.6004	557.9309	559.9141	549.0095	560.0276
11	435.5907	505.2856	549.6949	552.7795	507.5298	511.3846
12	434.4769	534.9901	612.7166	635.8219	606.6082	618.1407

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.000

ORDER OF THE PERIODIC AR 1 2 5 1 2 4 1 2 2 3 1 4

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	352.8376	426.9661	556.6456	637.8375	626.8080	628.7877
2	288.5665	442.2318	584.4014	663.6298	678.6229	713.1401
3	263.0909	460.2608	618.2681	718.2829	771.0497	811.7137
4	333.0618	526.9001	674.1971	764.0195	817.6433	849.9848
5	309.1595	426.9753	543.3387	612.3805	652.1103	665.7551
6	323.2480	432.5580	516.7115	571.9523	589.6813	598.7465
7	366.4035	466.5959	539.0062	575.0883	572.9020	568.3068
8	360.0987	459.0664	530.4035	562.0706	556.6434	544.6187
9	391.7921	490.7141	561.8072	570.1472	564.9072	561.5855
10	384.7542	475.0822	543.6483	541.0540	526.9179	536.8158
11	433.6461	498.3168	538.3614	537.6835	489.0784	492.1431
12	428.7050	521.0616	593.7216	612.6185	579.4034	589.5884

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.100

ORDER OF THE PERIODIC AR 1 2 5 1 2 4 1 2 2 3 1 4

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	355.6810	408.5848	495.5063	547.5602	511.2219	503.5265
2	325.2082	403.0595	493.3419	537.1554	524.3084	547.2028
3	268.0506	370.7203	474.5008	539.6736	566.2270	591.4097
4	307.3249	427.0913	527.3463	585.0973	616.1710	633.6028
5	337.7860	386.6690	448.4180	481.0988	497.2611	495.7021
6	342.7083	398.2050	433.8602	456.9221	452.5585	451.3807
7	383.1701	441.0004	473.1189	480.3960	460.0584	450.0013
8	369.8798	414.7848	440.0659	437.0566	406.1112	382.0773
9	395.7649	440.8116	468.1143	437.2493	405.8158	391.2104
10	388.1418	428.4734	458.5112	418.6548	379.0094	381.9203
11	437.9561	465.9868	472.1354	441.9786	368.8449	368.0493
12	420.3929	455.4975	488.9161	475.5136	414.1743	416.9526

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.200

ORDER OF THE PERIODIC AR 1 2 5 1 2 4 1 2 2 3 1 4

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	356.6723	410.7813	481.2392	522.2570	481.9494	478.9588
2	333.8411	403.9448	475.7973	506.6722	489.0059	511.6074
3	288.1740	360.9994	439.5707	488.0642	504.9372	526.7198
4	306.7745	393.1878	468.9613	510.2578	531.5435	545.2472
5	360.9773	390.0189	426.8120	443.2908	451.8494	450.3749
6	359.4193	396.5839	409.3094	418.0777	408.4510	409.9927
7	398.1955	441.1538	455.2525	451.5353	430.8648	428.0938
8	391.3680	419.2554	424.6300	408.6690	376.2155	361.2144
9	413.3911	439.6475	447.1953	401.3182	366.6589	358.3804
10	408.4022	430.9405	444.2497	391.4238	350.4252	357.6684
11	452.1331	466.5746	459.0673	418.6122	347.7802	353.1862
12	440.1511	455.3059	472.5854	448.5685	389.4433	396.4792

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.300

ORDER OF THE PERIODIC AR 1 2 5 1 2 4 1 2 2 3 1 4

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	356.0236	409.4006	471.8263	508.0323	468.8912	471.8942
2	331.4665	399.8647	463.7435	488.9984	472.3333	496.2953
3	296.9394	356.4295	421.8906	461.5256	475.1286	496.8244
4	305.8532	373.6016	434.7558	466.7147	483.7274	497.4318
5	372.6390	391.1730	412.8583	421.1275	427.8226	429.7434
6	368.8903	395.9288	394.5500	396.4079	387.4591	393.6797
7	405.1316	438.8148	441.5841	432.8203	416.0938	420.2413
8	406.2763	426.8651	421.8596	401.7175	375.4052	371.0992
9	424.5050	441.4435	437.8113	386.1173	355.8723	355.5460
10	422.0369	436.1678	440.9018	383.8699	348.8922	360.0522
11	461.2917	467.4367	452.2783	407.1508	344.2770	353.9210
12	454.9577	460.1039	469.2595	441.5393	391.2639	401.6198

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.400

ORDER OF THE PERIODIC AR 1 2 5 1 2 4 1 2 2 3 1 4

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	355.7589	406.7537	463.8816	497.2837	460.1617	467.9689
2	327.2451	392.9945	451.7291	473.3984	458.8055	483.5888
3	301.8873	352.2307	408.6036	442.2930	454.9321	477.0328
4	305.2492	360.2770	410.9000	436.7493	451.8542	466.5048
5	380.2144	390.8240	400.4828	403.8531	410.6054	415.8505
6	376.1238	395.9619	383.7377	381.9593	375.6442	385.6219
7	409.7178	435.9221	429.6254	418.2213	406.2089	415.1005
8	417.2343	433.0760	420.6111	399.3920	380.2503	383.5335
9	431.6566	441.8806	429.6798	375.4097	350.9940	356.1697
10	431.1093	439.4556	438.2037	379.5839	351.4424	363.9729
11	468.3351	467.4729	446.4255	398.1808	343.4792	354.2137
12	466.8552	464.2313	467.4665	437.6524	395.9045	407.0110

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.500

ORDER OF THE PERIODIC AR 1 2 5 1 2 4 1 2 2 3 1 4

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	356.3539	405.2936	458.9310	490.7148	456.0753	467.6959
2	323.6158	386.3617	441.4187	460.5602	448.5302	473.5928
3	306.1206	349.7790	399.3221	428.9084	441.9299	464.3694
4	305.8076	351.9115	394.6017	416.5704	431.1873	447.0079
5	386.7089	391.2440	390.6773	391.5881	399.3557	407.2956
6	382.9465	397.6906	376.8656	373.8492	371.0279	383.5775
7	414.1788	434.4446	420.7480	408.5733	401.4127	413.2564
8	426.4365	438.8272	420.4491	400.0275	387.7384	395.8701
9	437.1476	442.0791	422.7129	368.0438	349.5906	357.9934
10	438.1682	442.0207	436.0962	377.4306	355.8424	367.8175
11	475.5790	468.6810	442.9541	392.7397	346.0798	355.7828
12	478.6654	469.4342	467.9013	436.8406	402.7648	412.9913

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS ARE NOT UPDATED

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	353.4205	601.0446	748.2652	783.5103	729.3923	698.9888
2	290.6818	627.6978	784.6112	818.3734	789.2279	791.9778
3	221.9000	671.0635	830.2269	879.9011	887.6000	898.2351
4	277.9656	722.0674	870.2158	913.2961	924.2509	928.2263
5	301.1354	589.3477	719.7688	749.6931	749.9989	737.1621
6	320.9135	570.5792	674.1671	695.0388	677.0449	681.0348
7	361.1196	587.6233	679.1170	686.3122	651.9765	623.9625
8	353.0927	578.1605	668.2141	673.3914	638.2633	604.8434
9	379.2253	603.1118	691.6028	678.2189	644.7232	620.8026
10	371.0473	574.4128	659.1996	638.5645	599.3674	589.9630
11	431.0634	582.6342	643.4437	625.9318	555.6657	539.9464
12	554.1054	684.9068	725.2981	711.9468	653.7122	645.6501

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.000

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	352.8376	589.3116	731.3388	764.6849	708.5143	677.5284
2	296.1136	608.8471	759.7479	790.9212	759.2826	761.2236
3	223.3739	642.5788	796.2045	843.4759	849.0560	858.3281
4	275.6366	697.7000	840.7505	881.5562	890.8653	893.5908
5	306.2403	570.4880	695.0145	722.3271	720.8538	706.5646
6	323.5088	556.5912	654.6209	673.1836	653.4641	636.6403
7	362.3629	576.0510	662.6123	667.5829	631.7217	603.3093
8	353.8073	562.8109	647.6287	650.1154	612.7525	578.1230
9	379.5570	587.3367	670.7422	654.0752	618.3024	593.3105
10	371.1084	560.2788	640.6026	616.8289	575.4276	565.5759
11	430.5263	571.6085	628.0197	607.9977	535.3325	519.5090
12	538.7119	662.8696	700.9684	685.4534	624.4515	615.8291

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.100

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	355.6810	519.4944	620.0059	639.1044	568.8942	536.9650
2	331.0316	511.6215	615.8126	628.1534	580.9899	580.4544
3	265.1841	492.0675	600.8881	630.2184	621.7488	624.0471
4	282.2106	546.5474	648.6347	671.8386	669.3453	664.6842
5	349.3250	472.4849	549.3715	556.7961	543.7017	522.4528
6	349.9394	474.7455	527.3818	527.7231	496.2290	476.5814
7	384.3032	509.5472	556.1858	544.2197	499.4511	472.5656
8	376.5623	474.1109	515.2228	496.1508	442.8790	403.1551
9	399.7600	494.9622	536.3351	492.9601	440.3904	410.9208
10	391.5462	475.1771	517.8255	467.8824	409.6387	399.4496
11	443.6496	506.1396	526.5339	486.4181	396.7055	383.7834
12	460.4660	530.4064	550.5060	518.9688	439.5572	431.0139

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.200

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	356.6723	500.2541	582.0877	596.4271	527.0966	504.6919
2	336.9332	490.2598	574.3973	580.2006	533.5347	537.7316
3	287.8792	453.0647	539.3088	560.3040	548.4875	552.2075
4	292.2176	485.9341	566.1676	580.4774	573.9604	569.8333
5	372.2101	450.0720	501.9962	500.6404	486.1690	469.7054
6	366.6871	451.2267	479.8668	472.3090	440.8148	428.3232
7	399.6340	491.3907	518.1949	500.2208	459.6349	444.1827
8	399.2498	458.7015	478.0048	451.2692	401.1281	374.7490
9	420.6852	474.3384	494.3421	440.6160	389.4661	370.7619
10	415.6191	459.8083	483.9569	424.8801	369.4848	368.3659
11	459.9842	491.5770	495.4467	448.5576	384.1788	382.1857
12	454.0135	498.3647	510.6135	475.5550	402.7844	403.6041

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.300

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	356.0236	487.9560	560.2877	572.9933	507.4738	493.9405
2	333.1989	476.2456	550.8378	553.9015	510.9323	519.2188
3	297.3765	433.5070	507.3262	523.8115	512.2410	518.7152
4	297.1402	450.9447	518.0711	527.4005	520.0142	518.5148
5	384.4292	437.4049	473.7463	468.0840	455.3961	445.2321
6	376.7999	438.5589	452.1052	441.0545	413.3946	408.3989
7	407.7557	478.6615	493.0622	472.7930	438.9333	433.0619
8	414.3145	456.5375	463.6960	435.1691	393.9007	381.0212
9	433.4785	465.9247	473.3353	415.8981	371.9529	364.1643
10	430.9613	455.9118	470.0526	408.3721	381.5396	387.3683
11	471.1199	483.6345	478.0441	428.3849	354.0290	359.4139
12	455.3835	485.7890	494.0286	459.0437	398.0434	405.3010

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.400

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	355.7589	477.8842	544.0458	556.1114	494.5003	487.8214
2	328.3340	462.9291	531.4056	532.7810	493.7191	504.6442
3	303.3545	419.2404	484.3647	497.8559	487.7876	496.6546
4	300.4931	426.9470	484.5670	490.8076	483.9640	485.3309
5	393.1740	427.3630	451.3057	443.4695	433.5680	428.8613
6	384.9051	430.2963	432.1880	419.8405	397.1920	398.0391
7	413.9140	468.1263	472.7559	451.8634	424.9483	425.8007
8	425.5731	456.4056	454.7980	426.7177	394.7479	391.4592
9	442.1670	459.2984	457.0849	398.4431	362.5774	362.4731
10	441.4653	453.0717	460.1619	397.9479	360.0030	369.2520
11	480.3905	476.8452	464.0662	412.7469	348.4529	357.2941
12	456.9116	476.9097	482.3124	448.0833	398.1450	408.3659

TRANSFER-FUNCTION FORECASTS
NIAGARA RIVER FLOWS 1961 - 1984

MEANS UPDATED USING EXPONENTIAL SMOOTHING WIHT ALPHA =0.500

ORDER OF THE PERIODIC AR 1 1 1 1 1 1 1 1 1 1 1 1

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	356.3539	471.1621	533.1973	545.2068	487.5090	486.1427
2	324.4008	451.5755	515.7667	516.0443	480.9382	493.4244
3	308.5198	409.4315	467.9902	479.5426	471.7702	482.4464
4	303.7226	410.8284	461.2028	465.7501	460.2992	464.2781
5	400.8338	420.4887	433.8677	425.5997	418.9449	418.5754
6	392.4052	426.0562	418.5836	406.6689	389.4557	394.4519
7	419.8084	460.7826	457.4525	437.3392	417.1708	422.4808
8	435.1418	457.6297	449.1080	422.9250	399.5854	402.5850
9	449.0774	454.1301	443.8927	385.9090	357.9532	362.7337
10	449.8369	451.0296	452.6439	391.2034	361.5867	371.7135
11	489.8200	472.3690	453.8661	401.7998	347.3897	356.9725
12	459.9117	471.2845	474.5113	441.4485	401.5116	412.5151

MONTHLY AVERAGES OF LAKE ERIE ELEVATIONS AT CLEVELAND - FEET - (1860-1984)

ITERATIVE SPECTRAL ESTIMATION FREQUENCIES (1, 8, 11, 22, 36, 100)

MEAN OF THE SERIES: 0.5706E+03
STND DEVIATION OF THE SERIES: 0.7055E+00

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	0.9162	0.9267	0.9709	1.0565	1.1162	1.1210
2	0.9843	0.9896	1.0352	1.1152	1.1859	1.2125
3	1.1274	1.1644	1.2274	1.3137	1.3912	1.4446
4	1.2406	1.2810	1.3404	1.4187	1.4931	1.5461
5	1.1072	1.1340	1.1864	1.2610	1.3288	1.3716
6	0.9814	1.0063	1.0574	1.1362	1.1946	1.2187
7	0.8748	0.8921	0.9387	1.0108	1.0484	1.0325
8	0.8208	0.8372	0.8825	0.9494	0.9589	0.9082
9	0.7911	0.8137	0.8598	0.9176	0.9022	0.8363
10	0.7979	0.8226	0.8856	0.9465	0.9031	0.8317
11	0.7741	0.7853	0.8525	0.9134	0.8730	0.8318
12	0.8875	0.8884	0.9376	0.9876	0.9823	0.9957

FORECAST OBTAINED USING THE SEASONAL TRANSFER FUNCTION MODEL
NIAGARA RIVER FLOWS 1961 - 1984

MEAN OF THE SERIES: 0.5706E+03
STND DEVIATION OF THE SERIES: 0.7055E+00

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	594.3947	587.6702	606.8164	657.7880	644.9432	616.6883
2	585.0008	574.2451	586.5147	628.3433	629.5082	634.6602
3	602.7698	624.1032	664.5853	723.3885	763.4926	781.4012
4	732.6461	761.6661	803.1162	857.0711	903.7300	923.3567
5	587.1596	608.2642	644.4724	696.8467	739.1517	739.9632
6	529.5991	549.5355	566.6865	614.2569	635.2204	622.2828
7	545.2585	557.5971	570.0622	610.5758	608.9780	561.5202
8	577.6914	585.2384	592.8030	622.1206	600.3159	514.1875
9	631.7774	643.3496	655.0117	659.4527	627.9714	541.0395
10	626.8336	625.2845	637.4688	625.9940	572.7603	498.1195
11	622.6542	614.6474	618.7863	632.8297	569.1896	512.7201
12	533.5536	529.3232	559.0502	583.6271	520.9271	472.3166

MONTHLY AVERAGES OF LAKE ERIE ELEVATIONS AT CLEVELAND - FEET - (1860-1984)

NIN-ITERATIVE SPECTRAL ESTIMATION ALL FREQUENCIES (1, 8, 11, 22, 36, 100)

MEAN OF THE SERIES: 0.5706E+03
STND DEVIATION OF THE SERIES: 0.6579E+00

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	1.0698	1.0522	1.0679	1.1318	1.1809	1.1798
2	1.1281	1.1081	1.1272	1.1882	1.2516	1.2765
3	1.2815	1.2880	1.3240	1.3929	1.4640	1.5155
4	1.3921	1.4027	1.4372	1.4999	1.5673	1.6158
5	1.2560	1.2546	1.2829	1.3423	1.4034	1.4412
6	1.1275	1.1237	1.1500	1.2129	1.2648	1.2838
7	1.0134	1.0027	1.0246	1.0814	1.1138	1.0935
8	0.9486	0.9393	0.9621	1.0148	1.0195	0.9623
9	0.9144	0.9144	0.9415	0.9867	0.9650	0.8871
10	0.9159	0.9184	0.9634	1.0145	0.9675	0.8839
11	0.8851	0.8754	0.9245	0.9768	0.9345	0.8838
12	0.9894	0.9722	1.0052	1.0464	1.0366	1.0412

FORECAST OBTAINED USING THE SEASONAL TRANSFER FUNCTION MODEL
NIAGARA RIVER FLOWS 1961 - 1984

MEAN OF THE SERIES: 0.5706E+03
STND DEVIATION OF THE SERIES: 0.6579E+00

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	682.0599	664.3593	669.9896	708.3125	689.3271	655.1527
2	673.5660	650.7772	648.2226	677.7771	675.3127	679.4185
3	699.2799	703.5903	728.2787	776.0320	811.2860	826.1659
4	829.2547	840.5263	866.8432	910.6825	952.3967	968.0065
5	685.4108	690.0067	711.5638	753.5028	790.3775	786.1600
6	619.9344	625.6500	631.5153	668.7090	683.1931	662.3829
7	618.4965	620.0781	623.7603	656.7288	651.7390	598.8888
8	642.7712	640.7634	640.1282	662.0413	635.4922	540.8326
9	692.3329	695.5251	699.9356	698.9511	662.8193	566.0380
10	678.9469	673.6485	681.4578	686.5617	608.4007	520.5557
11	672.4042	659.2390	658.5956	669.4348	604.6448	540.9015
12	592.2581	578.8977	600.5321	621.8189	559.8162	505.4293

LAKE ERIE MONTHLY ELEVATIONS AT CLEVELAND FROM JAN(1961)-DEC(1984)

FORECASTS OBTAINED USING THE ROUTING MODEL

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	0.2157	0.5988	0.8473	1.0424	1.1800	1.2861
2	0.3539	0.7105	0.9499	1.1383	1.2685	1.3785
3	0.6251	0.9938	1.2484	1.4396	1.5925	1.7224
4	0.8215	1.1653	1.4029	1.5911	1.7513	1.8851
5	0.6583	0.9573	1.1840	1.3641	1.5072	1.6289
6	0.5119	0.8160	1.0316	1.2088	1.3372	1.4452
7	0.4778	0.7492	0.9563	1.1039	1.2151	1.3133
8	0.4643	0.7064	0.8948	1.0351	1.1314	1.2199
9	0.4411	0.6670	0.8607	0.9898	1.0729	1.1621
10	0.4614	0.6703	0.8542	0.9729	1.0377	1.1151
11	0.5164	0.7080	0.8853	1.0076	1.0691	1.1522
12	0.6788	0.8762	1.0538	1.1645	1.2409	1.3345

NIAGARA RIVER FLOW FORECASTS USING THE ROUTING MODEL
AND THE SEASONAL TRANSFER FUNCTION

NUMBER OF YEARS USED TO ESTIMATE THE STD.DEV = 24

NIAGARA RIVER FLOWS 1961 - 1984

OBSERVED FORECAST ERRORS

MONTH	1	2	3	4	5	6
1	339.7379	382.2415	488.9925	587.0310	609.9460	649.8379
2	294.0089	389.0890	506.9150	604.8783	644.5671	709.0075
3	271.2016	485.7464	638.7100	753.7966	838.8627	912.5131
4	432.7666	651.6757	800.2528	915.5102	1011.8420	1089.2614
5	290.3899	460.7846	596.2738	701.8757	785.9413	849.8221
6	272.0074	399.1551	492.6963	586.2226	647.9302	699.0064
7	326.0337	401.6985	472.6245	535.9362	571.2617	606.3883
8	365.1115	405.7798	452.4253	499.8144	519.2262	540.8983
9	397.7228	431.8824	484.6413	495.3891	508.9234	529.4987
10	405.4304	419.5085	460.4338	457.3652	454.7048	483.4090
11	437.7925	449.8049	470.3551	483.4081	459.6329	486.1765
12	393.7081	454.7635	535.1584	572.1161	568.3164	605.9367

---------- MONTH=1 ----------

YEAR

METHOD	1 RANK	2 RANK	3 RANK	4 RANK	5 RANK	6 RANK
NON	1	13	17	21	22	22
N00	3	19	18	22	23	24
N01	5	12	15	16	18	19
N02	7	7	3	10	15	17
N03	9	5	4	4	7	14
N04	11	3	2	2	2	6
N05	13	1	1	1	1	1
N1N	1	21	25	27	27	28
N10	3	22	26	28	28	29
N11	5	16	20	20	20	21
N12	7	9	13	15	17	18
N13	9	6	6	9	12	15
N14	11	4	5	5	8	13
N15	13	2	3	3	4	8
NEON	18	20	24	25	25	25
NE00	16	17	21	23	24	23
NE01	20	13	14	12	14	11
NE02	28	15	11	11	9	5
NE03	24	14	10	8	6	4
NE04	22	11	9	7	5	3
NE05	26	10	7	6	3	2
NE1N	18	30	31	31	31	31
NE10	16	29	30	30	30	30
NE11	20	27	28	24	19	16
NE12	28	26	24	19	16	12
NE13	24	25	22	17	13	10
NE14	22	24	19	14	11	9
NE15	26	23	16	12	10	7
SPEN	31	31	29	29	29	27
SPEI	30	28	27	26	26	20
ROUT	15	8	12	18	21	26

---------- MONTH=2 ----------

METHOD	YEAR 1 RANK	2 RANK	3 RANK	4 RANK	5 RANK	6 RANK
N0N	28	24	24	25	26	26
N00	26	22	23	23	23	24
N01	16	15	14	17	18	19
N02	12	10	9	10	14	16
N03	10	5	4	5	7	11
N04	8	3	2	2	3	4
N05	6	1	1	1	1	1
N1N	28	26	28	29	29	29
N10	26	25	27	28	28	28
N11	16	16	18	19	20	21
N12	12	13	13	15	17	17
N13	10	6	8	9	12	14
N14	8	4	5	7	9	9
N15	6	2	3	3	5	5
NE0N	1	19	25	27	27	27
NE00	2	17	21	24	25	25
NE01	18	12	12	14	15	15
NE02	24	14	11	11	10	10
NE03	22	11	10	8	6	7
NE04	19	9	7	6	4	3
NE05	14	7	6	4	2	2
NE1N	3	30	31	31	31	31
NE10	5	29	30	30	30	30
NE11	21	27	26	21	19	18
NE12	25	23	20	18	16	13
NE13	23	21	19	16	13	12
NE14	20	20	17	13	11	8
NE15	15	18	16	12	8	6
SPEN	31	31	29	26	24	22
SPEI	30	28	22	22	21	20
ROUT	4	8	15	20	22	23

---------- MONTH=3 ----------

METHOD	YEAR 1 RANK	2 RANK	3 RANK	4 RANK	5 RANK	6 RANK
N0N	27	25	25	24	24	25
N00	26	24	22	21	22	23
N01	24	15	16	18	18	19
N02	16	12	10	13	14	15
N03	13	6	6	7	10	11
N04	11	2	2	3	4	5
N05	14	1	1	1	2	2
N1N	29	27	28	29	28	29
N10	28	26	27	27	27	27
N11	25	18	19	19	20	20
N12	19	13	15	16	17	17
N13	15	10	11	12	13	13
N14	10	5	7	8	9	9
N15	12	3	4	5	5	6
NE0N	0	21	24	25	25	26
NE00	3	20	21	22	23	22
NE01	5	11	13	15	16	16
NE02	9	9	9	10	11	12
NE03	17	8	8	6	7	8
NE04	20	7	5	4	3	3
NE05	22	4	3	2	1	1
NE1N	1	30	31	31	31	30
NE10	2	29	30	30	30	28
NE11	4	23	20	20	19	18
NE12	8	19	18	17	15	14
NE13	18	17	17	14	12	10
NE14	21	16	14	11	8	7
NE15	23	14	12	9	6	4
SPEN	31	31	29	28	26	24
SPEI	30	28	26	23	21	21
ROUT	7	22	23	26	29	31

---------- MONTH=4 ----------

METHOD	YEAR 1 RANK	2 RANK	3 RANK	4 RANK	5 RANK	6 RANK
NON	26	24	23	23	23	23
NOO	25	23	21	21	21	21
NO1	21	17	17	18	18	19
NO2	12	11	12	14	14	15
NO3	8	7	7	8	10	12
NO4	4	3	4	4	7	7
NO5	2	1	1	2	4	6
N1N	28	26	26	26	26	27
N10	27	25	25	25	25	25
N11	22	18	19	19	20	20
N12	20	13	14	15	16	16
N13	10	9	11	12	13	14
N14	7	6	8	9	9	10
N15	6	4	5	5	8	9
NEON	24	21	24	24	24	24
NEOO	23	20	22	22	22	22
NE01	19	15	16	17	17	17
NE02	18	10	10	11	12	11
NE03	17	8	6	7	5	5
NE04	15	5	3	3	2	3
NE05	16	2	2	1	1	1
NE1N	3	29	31	30	29	29
NE10	1	28	29	28	27	26
NE11	5	22	20	20	19	18
NE12	9	19	18	16	15	13
NE13	11	16	15	13	11	8
NE14	13	14	13	10	6	4
NE15	14	12	9	6	3	2
SPEN	31	31	30	29	30	30
SPEI	30	30	28	27	28	28
ROUT	29	27	27	31	31	31

---------- MONTH=5 ----------

METHOD	YEAR 1 RANK	2 RANK	3 RANK	4 RANK	5 RANK	6 RANK
NON	17	22	22	22	23	23
N00	16	21	20	21	21	22
N01	3	10	16	18	19	19
N02	2	7	9	13	14	16
N03	4	4	4	6	9	12
N04	8	2	2	2	5	7
N05	14	1	1	1	2	4
N1N	19	27	27	26	26	27
N10	18	25	25	25	25	25
N11	10	15	19	20	20	20
N12	6	8	15	16	17	18
N13	5	6	10	12	13	14
N14	9	5	6	7	10	11
N15	12	3	3	4	6	9
NEON	13	20	24	24	24	24
NE00	15	17	21	23	22	21
NE01	20	9	13	15	16	15
NE02	22	11	11	10	11	10
NE03	24	13	8	8	7	6
NE04	25	12	7	5	3	2
NE05	27	14	5	3	1	1
NE1N	7	29	31	30	29	28
NE10	11	28	29	29	27	26
NE11	21	26	23	19	18	17
NE12	23	23	18	17	15	13
NE13	26	19	17	14	12	8
NE14	28	18	14	11	8	5
NE15	29	16	12	9	4	3
SPEN	31	31	30	31	31	30
SPEI	30	30	28	27	28	29
ROUT	1	24	26	28	30	31

---------- MONTH=6 ----------

METHOD	YEAR 1 RANK	2 RANK	3 RANK	4 RANK	5 RANK	6 RANK
NON	4	18	22	22	22	22
NOO	6	17	21	21	21	23
NO1	8	9	16	18	19	19
NO2	3	7	9	13	15	17
NO3	2	4	4	6	10	13
NO4	5	2	2	2	4	8
NO5	11	1	1	1	1	3
N1N	14	26	27	27	26	27
N10	15	25	26	26	25	28
N11	13	16	19	20	20	20
N12	12	8	13	16	17	18
N13	9	6	8	12	13	15
N14	7	5	5	7	9	11
N15	10	3	3	3	5	7
NEON	17	23	25	25	24	24
NEOO	18	21	23	23	23	21
NE01	20	14	15	15	16	14
NE02	22	12	11	10	11	10
NE03	24	10	10	8	6	4
NE04	25	11	7	5	3	2
NE05	27	13	6	4	2	1
NE1N	16	30	31	31	30	29
NE10	19	29	30	30	29	26
NE11	21	27	24	19	18	16
NE12	23	24	18	17	14	12
NE13	26	22	17	14	12	9
NE14	28	20	14	11	8	6
NE15	29	19	12	9	7	5
SPEN	31	31	29	29	31	30
SPEI	30	28	28	28	27	25
ROUT	1	15	20	24	28	31

---------- MONTH=7 ----------

	YEAR					
	1	2	3	4	5	6
	RANK	RANK	RANK	RANK	RANK	RANK
METHOD						
NON	1	13	19	21	20	21
NOO	4	15	20	22	22	24
NO1	8	10	16	18	19	19
NO2	6	7	8	13	16	17
NO3	2	4	4	5	11	14
NO4	3	2	2	2	3	9
NO5	5	1	1	1	1	1
N1N	12	23	26	26	26	27
N10	14	24	27	27	28	30
N11	13	18	22	23	21	23
N12	11	9	13	16	18	18
N13	10	6	7	10	15	16
N14	9	5	5	6	9	13
N15	7	3	3	3	5	8
NEON	18	22	24	25	25	25
NEOO	18	20	23	24	24	22
NE01	20	16	17	15	14	12
NE02	22	17	11	11	10	7
NE03	24	14	10	8	6	4
NE04	26	12	9	7	4	3
NE05	28	11	6	4	2	2
NE1N	16	30	31	31	31	31
NE10	17	29	30	30	29	28
NE11	21	27	25	20	17	15
NE12	23	26	21	17	13	11
NE13	25	25	18	14	12	10
NE14	27	21	15	12	8	6
NE15	29	19	12	9	7	5
SPEN	31	31	29	29	30	26
SPEI	30	28	28	28	27	20
ROUT	15	8	14	19	23	29

---------- MONTH=8 ----------

	YEAR 1	2	3	4	5	6
	RANK	RANK	RANK	RANK	RANK	RANK
METHOD						
NON	3	16	21	22	22	25
N00	6	17	22	23	23	26
N01	4	10	17	18	19	19
N02	1	7	7	13	16	17
N03	2	4	4	4	12	15
N04	5	2	2	2	4	10
N05	10	1	1	1	1	7
N1N	13	25	26	26	26	29
N10	14	26	27	27	27	30
N11	12	15	20	21	21	21
N12	11	8	13	17	18	18
N13	8	6	6	10	15	16
N14	7	5	5	5	10	14
N15	9	3	3	3	6	11
NEON	18	24	25	25	25	27
NE00	17	23	24	24	24	24
NE01	20	11	12	15	14	5
NE02	22	12	11	9	3	1
NE03	24	13	10	8	2	2
NE04	26	14	9	6	5	6
NE05	28	18	8	7	7	9
NE1N	15	29	31	31	31	31
NE10	16	28	30	29	29	28
NE11	21	27	23	19	17	13
NE12	23	22	19	16	13	3
NE13	25	20	18	14	8	4
NE14	27	19	16	12	9	8
NE15	29	21	14	11	11	12
SPEN	31	31	29	30	30	22
SPEI	30	30	28	28	28	20
ROUT	19	9	15	20	20	23

---------- MONTH=9 ----------

	YEAR					
	1	2	3	4	5	6
METHOD	RANK	RANK	RANK	RANK	RANK	RANK
NON	11	18	21	22	22	25
NOO	12	19	22	23	23	26
NO1	9	10	18	18	19	19
NO2	7	7	9	14	16	17
NO3	1	4	5	7	13	15
NO4	1	2	2	2	9	12
NO5	6	1	1	1	4	9
N1N	13	26	26	26	26	29
N10	14	27	27	27	27	30
N11	10	21	20	21	21	22
N12	8	8	15	17	18	18
N13	4	6	7	12	15	16
N14	3	5	4	6	12	14
N15	5	3	3	3	10	10
NEON	18	25	25	25	25	27
NEOO	17	23	24	24	24	23
NE01	19	12	14	15	14	11
NE02	22	11	12	11	7	4
NE03	24	13	10	9	3	1
NE04	25	14	8	5	2	2
NE05	27	15	6	4	1	3
NE1N	15	29	30	30	30	31
NE10	16	28	29	28	28	28
NE11	21	24	23	19	17	13
NE12	23	22	19	16	11	8
NE13	26	20	16	13	8	7
NE14	28	17	13	10	6	5
NE15	29	16	11	8	5	6
SPEN	31	31	31	31	31	24
SPEI	30	30	28	29	29	21
ROUT	20	9	17	20	20	20

---------- MONTH=10 ----------

YEAR

METHOD	1 RANK	2 RANK	3 RANK	4 RANK	5 RANK	6 RANK
NON	11	17	21	22	22	25
N00	12	18	22	23	23	26
N01	9	9	17	19	20	20
N02	7	7	7	13	16	17
N03	2	5	5	5	12	14
N04	3	3	3	3	3	5
N05	6	1	1	1	1	1
N1N	13	26	26	26	26	29
N10	14	27	27	27	27	30
N11	10	16	20	21	21	22
N12	8	8	12	17	18	18
N13	4	6	6	9	15	16
N14	1	4	4	4	8	12
N15	5	2	2	2	2	2
NE0N	18	25	25	25	25	27
NE00	17	23	24	24	24	24
NE01	19	11	14	15	14	13
NE02	22	12	11	11	5	3
NE03	24	13	10	8	4	4
NE04	26	14	9	7	6	6
NE05	27	15	8	6	7	8
NE1N	15	29	30	30	30	31
NE10	16	28	29	28	29	28
NE11	20	24	23	20	17	15
NE12	23	22	19	16	13	9
NE13	25	21	18	14	10	7
NE14	28	20	15	12	9	10
NE15	29	19	13	10	11	11
SPEN	31	31	31	31	31	23
SPEI	30	30	28	29	28	21
ROUT	21	10	16	18	19	19

---------- MONTH=11 ----------

YEAR

METHOD	1 RANK	2 RANK	3 RANK	4 RANK	5 RANK	6 RANK
NON	11	13	21	22	24	26
NOO	12	16	22	24	25	29
NO1	9	9	17	20	20	21
NO2	7	7	7	14	17	17
NO3	3	5	5	5	14	15
NO4	2	3	3	3	12	12
NO5	6	1	1	1	8	7
N1N	13	24	26	26	27	30
N10	14	25	27	27	29	31
N11	10	18	20	21	23	25
N12	8	8	12	17	18	18
N13	4	6	6	11	16	16
N14	1	4	4	4	13	14
N15	5	2	2	2	10	11
NEON	18	26	25	25	22	22
NEOO	17	23	24	23	21	20
NEO1	20	11	16	15	11	10
NEO2	22	12	13	12	5	1
NEO3	24	14	10	9	2	2
NEO4	25	15	9	7	1	3
NEO5	27	17	8	5	3	4
NE1N	16	29	30	29	28	27
NE10	15	28	29	28	26	24
NE11	21	27	23	19	15	13
NE12	23	22	19	16	9	9
NE13	26	21	18	13	7	8
NE14	28	20	14	10	6	6
NE15	29	19	11	8	4	5
SPEN	31	31	31	31	31	28
SPEI	30	30	28	30	30	23
ROUT	19	10	15	18	19	19

---------- MONTH=12 ----------

	YEAR					
	1	2	3	4	5	6
	RANK	RANK	RANK	RANK	RANK	RANK
METHOD						
NON	17	22	24	24	26	25
N00	16	21	23	23	25	24
N01	7	16	18	19	19	21
N02	2	7	12	16	17	18
N03	6	5	5	10	14	15
N04	9	2	3	3	12	12
N05	14	3	1	1	9	9
N1N	19	28	29	29	29	30
N10	18	27	28	28	28	29
N11	10	20	21	20	21	22
N12	4	12	16	17	18	19
N13	3	6	9	13	16	16
N14	8	4	4	6	13	14
N15	12	1	2	2	10	11
NEON	13	26	27	27	27	28
NE00	11	23	25	25	24	23
NE01	5	10	14	14	11	10
NE02	15	9	10	11	1	1
NE03	21	11	8	8	2	2
NE04	26	13	6	5	3	5
NE05	27	14	7	4	7	8
NE1N	30	31	31	31	31	31
NE10	29	30	30	30	30	27
NE11	25	25	20	18	15	13
NE12	20	19	17	15	8	3
NE13	22	18	15	12	4	4
NE14	23	17	13	9	5	6
NE15	24	15	11	7	6	7
SPEN	31	29	26	26	22	20
SPEI	28	24	22	22	20	17
ROUT	1	8	19	21	23	26

APPENDIX C

FORECASTS

A program to forecast the Niagara River flows

USER MANUAL

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1. INTRODUCTION

FORECAST is a computer package developed by the Research Division of Ontario Hydro to obtain six years ahead forecasts values and their standard deviations for the Niagara River flows. **FORECAST** uses a combination of the routing model, developed at the Great Lakes Environmental Research Laboratory (GLERL) (Quinn, 1978; Hartmann 1987), and the periodic autoregressive model (PAR) (Pagano, 1978) as described in Camacho (1988).

The package consist of four programs and four data files. The programs are written in ANSI Fortran 77 and compiled with Micro-Soft FORTRAN V.4. The programs will run in an IBM-PC XT or AT compatible computer using the DOS operating system and having a minimum of 512K of RAM. The list of the files with a brief description of their purpose are given below.

FILE	DESCRIPTION
EXTLEV.EXE	obtains from file LAKES.DAT the end of the month Lake elevations to be used by the routing model
EXTNIG.EXE	obtains from file NIAGARA.DAT the Niagara River information to estimate the parameters of the PAR model
PARED.EXE	estimates the parameter of the Periodic Autoregressive model
FORC.EXE	obtains Niagara river flows forecasts and their standard errors.
LAKES.DAT	contains the historical data of the average elevation data for lakes Michigan-Huron, St. Clair and Erie.
NIAGARA.DAT	contains the historical data of the Niagara River flows.
NIA.DAT	contains the precipitation, run-off, diversion, ice retardation, evaporation and St. Mary's river flows data used by the routing model.
T_ON6712.DAT	contains estimates of the parameters of the PAR model using data from January 1860 to December 1967

The following sections describe how to use the FORECAST package.

2. INSTALLATION

You could install the programs:

- on one 1.2M floppy disk

- on the hard disk.

To install the programs on one 1.2 M floppy disk:

(i) Format your new 1.2M disk using the DOS format command. If your 1.2 M floppy is on drive A: use the command

```
FORMAT A: /S
```

The option /S copy the system file to the disk an so you could use the disk to boot the computer.

(ii) Insert disk No. 1 into drive B:\ and issue the command

```
COPY B:\*.* A:
```

(iii) Insert disk No. 2 into drive B:\ and issue the command

```
COPY B:\*.* A:
```

To install the programs on the hard disk:

(i) Insert disk No. 1 into drive A:\ and issue the command

```
COPY A:\*.* C:
```

(ii) Insert disk No. 2 into drive A:\ and issue the command

```
COPY A:\*.* C:
```

Once you have copy the files into either the hard disk or the 1.2 M disk you are ready to run the programs.

3. RUNNING THE PROGRAMS

3.1. OPTIONS AND LIMITATIONS

As was described in the introduction the **FORECAST** package was designed to obtain six years ahead Niagara River flows forecasts (on a monthly basis) and estimates for their standard deviations. The package is designed to give several options to the user. Some options are included to facilitate the normal use of the programs. Other options are included to allow the user to study the sensitivity of the forecast. The list of the options are listed below and explained latter in the text.

(i) The forecast can be started any month of the year.

(ii) The program can obtain up to seven years ahead forecasts.

(iii) The program can use up to 250 years of historical data to estimate the parameters of the PAR model.

(i) The program can use up to 50 years of historical data to estimate the forecast standard deviations.

(v) The user has the option to decide the transition point from the routing to the PAR model in the forecast model.

(i) The user can ask the program to list the forecasts obtained in the estimation of the forecast standard deviations.

3.2. BEFORE RUNNING THE PROGRAMS

Before running the programs the user have to do a little home work. One part is to update the LAKES.DAT and NIAGARA.DAT data files, and the other is to decide the parameters to be used in the calculation of the forecasts.

3.2.1. Updating the Data Files

The file LAKES.DAT contains historical monthly information of the Great Lakes elevations from 1900 to the present and the file NIAGARA.DAT historical monthly flows of the Niagara river from 1860 to present. It is vital for the good performance of the **FORECAST** package to maintain these files up to date.

The LAKES.DAT file contains the historical mean lake elevation (in feet) of the Lakes Michigan-Huron, St. Clair and Erie. Each group of data consists of three records of identification and a given number of data records corresponding to the number of years of historical data. Each data record consists of 13 data fields with format (12F6.2,4X,I4). The first 12 fields contain the monthly data from January to December of the year indicated in the last field.

To update the LAKES.DAT file use a text editor to enter the lake elevations at the end of each group of data. Make sure you use the same format as the present in the file. It is also necessary that the number of records for each lake be the same. If this is not the case, the program EXTLEV will abort.

The NIAGARA.DAT file contains historical monthly data of the Niagara River flows (in m^3). The first record of the file is an identification record and the remaining are data records. Each data record contains 12 fields with the average flow for January to December.

To update the NIAGARA.DAT file use a text editor to enter the new data at the end of the file. Type the new monthly values in the corresponding fields. During this process it is very important NOT to leave empty fields in the data records. If the data you have are expressed in CFPS multiply your data by 0.027 to convert them to m^3 before typing them to the data file.

It is recommended to update the LAKES.DAT and the NIAGARA.DAT files up to the same period of data. This will avoid inconsistencies in the data an unpredictable results on the forecasts.

3.2.2. Deciding the Parameters to Use

It is important to decide what parameters to use in the calculation of the forecasts before running the program for at least two reasons: (i) it assures consistency in the preparation of the data files; and (ii) it determines what input files to prepare and what programs to run.

The parameters to select are:

(i) The index of the month to initiate the calculation of the forecasts: this can be any value from 1 (corresponding to January) to 12 (corresponding to December). This value is required by the programs EXTLEV.

(ii) The number of years to use in comparing forecasts and historical values for the estimation of the forecast standard deviations. This can be any number between 0 and 50 (it is recommended to use about 20 years). This value is requested by the EXTLEV program in the preparation of the end of the month lake elevations file to be used in the FORC program. This value has to be smaller than or equal to the difference between the total number of historical years of the Niagara River flows available in the NIAGARA.DAT file and the number of years used to estimate the parameters of the PAR model. The program FORC checks for this requirement and if it is not meet, the program aborts.

(iii) The number of months the routing model is to be used in the calculation of the forecasts. Our analysis suggests that this number should be between six and eight and that it should not exceed 12.

(iv) Whether or not you want to update the parameter of the PAR model. If the user decides not to update the parameters of the PAR model (s)he should specify the file T_0n6712.dat or any previously prepared one as the T_file requested by the FORC program.

3.2.3. What to Do Next

After updating the data files and deciding the parameters to use in the program you are ready to run the programs. If you are not updating the parameters of the PAR model, run first the EXTLEV program and then the FORC program. If you are updating the parameters of the PAR model run in order the programs EXTNIG, PARED, EXTLEV and FORC.

3.3. RUNNING PROGRAM EXTNIG

The program EXTNIG is used to extract a given number of years from the NIAGARA.DAT file before estimating the parameters of the PAR model. The program can be run interactively or in batch.

Table 1 gives an example of the interactive run of the EXTNIG program. To initialize the program give the command

```
EXTNIG
```

The program will execute and give the following prompts to the user:

(i) FILE DESCRIPTOR FOR THE DATA SET

Enter the name of the file containing the historical Niagara River flows data. In the example is the NIAGARA.DAT.

(ii) ENTER NUMBER OF YEARS TO ESTIMATE ST.DV (<NNN)

This can be any number between 0 and the number of years contained in the historical data file. The number of years is the value given in brackets. This number can be thought of as the number of years *reserved* to estimate the forecast standard deviations (see 3.2.2. ii) and equals the number of years extracted from the complete data set before estimating the parameters of the PAR model. A number close to 20 is about right.

The program responds given the information of the last period of data to be used in the estimation of the parameters.

(iii) ENTER OUTPUT FILE NAME

This is the name of the file where the data for estimating the parameters of the PAR model is to be written. In the example of Table 1, the name given is N6712.DAT codifying the fact that the file contains data of the Niagara River flows up to December 1967.

The program can also run in batch by given the command

```
EXTNIG < infile
```

where the file *infile* is an input file containing three records:

(i) The name of the file with the Niagara river flows.
(ii) The number of years *reserved* to estimate the forecast standard deviations.
(iii) The name of the output file.

The bottom of Table 1 gives an example of this procedure, where the name of *infile* is INNIG. When you run the program in batch, the program will echo the prompts to the screen.

TABLE 1

Example of a run of the program EXTNIG

```
C:\EXTNIG
 FILE DESCRIPTOR FOR TIME SERIES DATA SET
NIAGARA.DAT
 ENTER NUMBER OF YEARS TO ESTIMATE ST.DV (<128)
20

The last month used to estimate the parameters
of the model was 1967 12
ENTER OUTPUT FILE NAME
N6712.DAT
Stop - Program terminated.
```

List of file INNIG

```
NIAGARA.DAT
20
N6712.DAT
```

The file INNIG is used to run the program in batch using the command

```
EXTNIG < INNIG
```

3.4. RUNNING PARED

The program PARED is used to estimate the parameters of the PAR model. You need to run this program only if you plan to update the parameters of the PAR model. Before running the program make sure you have prepared a file containing the information you want to use for the estimation of the parameters. The program EXTNIG will assist you in the preparation of this file.

Once you have prepared the file, you can run PARED interactively or in batch. Table 2 gives an example of how to run the program interactively. To start the program go to the directory where the file PARED.EXE is located and give the command

PARED

The program will execute and will prompt the user as follows.

(i) FILE DESCRIPTOR FOR THE TIME SERIES DATA SET

Enter the name of the data file you prepared containing the information you want to use to estimate the parameters of the model. The name of this file in the example given in Table 2 is N6712.dat. The program responds by writing to the screen the number of monthly periods in the file.

(ii) Enter Alpha the smooth constant to calculate the mean

The program uses single exponential smoothing with weight Alpha, α, to estimate the monthly means using the formula

$$Z_{s,t} = (1 - \alpha)Z_{s,t-1} + \alpha z_{s,t}$$

where $Z_{s,t}$ is the mean of season s at year t, and $z_{s,t}$ is the observation of the series of season s at year t. If $\alpha = 0$ then the estimate of the mean is given by

$$Z_{s,t} = (1 - 1/t)Z_{s,t-1} + (1/t)z_{s,t}.$$

If n years of data are available, the mean at time $t = n$ corresponds to the usual mean.

The value of α used in the estimation is the same value used in the updating of the means in the FORC program. Investigation of the sensibility of the forecast to the magnitude of this value suggests that α should be approximately 0.2. This is the value entered in Table 2.

The program produces three output files:

R_*file*:	Contains the list of the residuals of the model.
T_*file*	Contains the list of the estimated values requested by the FORC program.

PARED_*file* Contains a detailed output of the parameter estimates.

file is the name of the input file preceded by a number. If this number is larger than zero (0), it indicates that you have already used the same data file to estimate the parameters. It is also observed that only the first eight characters of the file name plus the extension is of any significance to DOS. For example the file PARED_ON6712.DAT is identified in DOS as PARED_ON.DAT: the other characters are ignored.

The program can also run in batch by given the command

PARED < *infile*

where the file *infile* is an input file containing two records: the name of the input file and the value of alpha, α. The bottom of Table 2 gives an example of this procedure, where the name of *infile* is INPAR. When you run the program in batch, the program will echo the prompts and the name of the output files to the screen.

TABLE 2

Example of a run of the program PARED
(The bold letters indicate the user input)

```
C:\PARED
 FILE DESCRIPTOR FOR TIME SERIES DATA SET
N6712.DAT

      1296 DATA POINTS INPUT
 Enter Alpha the smooth constant to calculate the mean
.2

-------> FILE OUTPUT ON:  R_ON6712.DAT

-------> FILE OUTPUT ON:  T_ON6712.DAT

-------> FILE OUTPUT ON:  PARED_ON6712.DAT
Stop - Program terminated.
```

List of file INPAR

```
N6712.DAT
.2
```

The file INFOR is used to run the program in batch using the command

PARED < INPAR

3.5. RUNNING EXTLEV

The program EXTLEV is used to prepared the file of end of the month elevations required by the FORC program. Before running the program make sure you have decided the month you want to start the forecasts and the number of years to be used to estimate the forecasts standard deviations (see Section 3.2.2). You can then run EXTLEV either interactively of in batch.

Table 3 gives an example of how to run the program interactively. To start the program go to the directory where the file EXTLEV.EXE is located and give the command

EXTLEV

The program will execute and will prompt the user as follows.

(i) FILE DESCRIPTOR FOR LAKE ELEVATION DATA SET

Enter the name of the file containing the historical information of the Lakes: LAKES.DAT. The program responds indicating the index of the lakes available in the file.

(ii) ENTER MONTH OF FIRST FORECAST

Enter the index of the month you want to start the forecast: 1 for January, 12 for December. The example of the Table gives 1.

(iii) ENTER THE NUMBER OF YEARS TO COMPARE FORECASTS

Enter the number of years you want to used to compare the forecasts and the historical data to estimate the forecast standard deviations. This number should be a number between 0 and 50 and is subject to the constraints given in Section 3.2.2.(ii). A number around 20 is about right. This is the value given in the Table.

The program responds indicating the year the first comparison is made. In the example of the Table this occurs in 1968.

(iv) ENTER OUTPUT FILE NAME

Enter the name of the file where the end of the month elevations are to be written. This file is used by the program FORC. In the Table the name given is L681.DAT codifying the fact that is a file containing Lake elevations for the January months (code 1) since 1968.

The program can also run in batch by given the command

EXTLEV < *infile*

where the file *infile* is an input file containing four records:

(i) The name of the Lakes data file
(ii) The index of the first month to obtain forecasts
(iii) The number of years to compare forecasts and historical values to estimate the forecast standard deviations
(iv) The name of the output file

The bottom of Table 3 gives an example of this procedure, where the name of *infile* is INLEV. When the program runs in batch, the program will echo the prompts and the year of the first comparison to the screen.

TABLE 3

Example of a run of the program EXTLEV
(The bold letters indicate the user input)

```
G:\EXTLEV
 FILE DESCRIPTOR FOR LAKE ELEVATION DATA SET
LAKES.DAT
reading lake           1
reading lake           2
reading lake           3
ENTER MONTH OF FIRST FORECAST
1
ENTER NUMBER OF YEARS TO COMPARE FORECASTS
20

THE FIRST COMPARISON IS IN YEAR 1968

ENTER OUTPUT FILE NAME
L681.DAT
Stop - Program terminated.
```

List of file INLEV

```
LAKES.DAT
1
20
L681.DAT
```

The file INLEV is used to run the program in batch using the command

EXTLEV < INLEV

3.6. RUNNING FORC

The program FORC is main program of the FORECAST package and is used to obtain the Niagara River flow forecasts. Before running the program make sure you have prepared the input file containing the end of the month Lake elevations, and you have available the T_file containing the estimates of the PAR model.

Once you have prepared the files, you can run FORC interactively or in batch. Table 4 gives an example of how to run the program interactively. To start the program go to the directory where the files FORC.EXE and NIA.DAT are located and give the command

FORC

The program will execute and will prompt the user as follows.

(i) ENTER OUTPUT FILE NAME

Enter the name of the data file where you want to store the forecasts. It is a good idea to use a code name for this file, so you can identify it latter. In the example of Table 4 we give the name F20881.OUT to codify the fact that is the output file of the forecasts starting January 1988 and using 20 years of data to estimate the forecast standard deviations.

(ii) ENTER T_FILE FOR THE FORECASTING

The T_file is an unformated file produced by the PARED program which lists all the information regarding the PAR model including the number of parameters, the order of the model for each month, the estimate of the parameters, the number of observations used to estimate the parameters, and the value of the smoothing constant to update the monthly means of the series.

You can use the file T_ON6712.DAT which contain estimates of the PAR model using data from January 1860 to December 1967. This file is included in the package. You also can obtain a new set of estimates using the PARED program (see Section 3.4).

(iii) FILE DESCRIPTOR FOR END OF MONTH ELEVATIONS

Enter the name of the file containing the end of the month elevations for Lakes Michigan-Huron, St. Clair and Erie. The file should have the format of the file listed in Table 5 and explained below.

a. The first record should contain an identification title.

b. The second record should contain the identification of the last year of data included in the file and the identification of the first month, m, to forecast.

c. The other records in the file should contain three fields each with the elevation at the end of the month m-1 of the lakes Michigan-Huron, St. Clair and Erie, respectively. The last record should correspond to the most recent information. The number of data records minus one gives the number of years used to compare the forecasts and the historical values in the estimation of the forecast standard errors.

The program EXTLEV can be used to prepare this file (see 3.5)

In the example given in Table 4, the name of this file is L681.DAT.

(iv) FILE DESCRIPTOR FOR THE TIME SERIES DATA SET

Enter the name of the data file containing all the historical information of the Niagara River flows. The name of this file is NIAGARA.DAT and is included in the FORECAST package. It is recommended to update this file as data become available (see Section 3.2). The program responds by writing to the screen the number of monthly periods in the file.

(v) ENTER NUMBER OF YEARS TO FORECAST (<=7)

The program has the capacity to forecast up to 7 year. Enter any value between 1 and 7 at this point. In the example of Table 4, this number is 3.

(vi) DO YOU WANT TO LIST ALL THE FORECAST

This is an option the program has to list all the forecast used for the comparison with the historical data in the estimation of the forecast standard errors. This information is useful to analyze how the model would have been performed in the past and under what circumstances the model seems to give poor forecasts. If you use this options a large output file will be produced. In the example of Table 4 this option is disable by entering N. Enter Y if you want to enable this option.

(vii) NUMBER OF MONTHS TO USE THE ROUTING MODEL

This is the number of periods the routing model is used in the calculation of the forecasts. Our analysis indicates that this number should be between 6 and 8. It is recommended not to use a number larger than 12. In the example of Table 4 a value of 6 is given. It is a good idea to decide the value of this entry before running the program (see Section 3.2.2).

After all the input is completed, the program reports to the screen the number of years it is necessary to update the monthly means before starting the forecasts. If this number is large, it is recommended to update the parameters of the PAR model using information up to the current year minus the number of years used in the estimation of the forecast standard deviations.

The program can also run in batch by given the command

PARED < *infile*

where the file *infile* is an input file containing seven records:

(i) The name of the file to write the forecasts.
(ii) The name of the file with the estimates of the parameters of the PAR model.
(iii) The name of the file with the end of the month elevations.
(iv) The name of the file with the historical Niagara River flows data.
(v) The number of years to obtain the forecasts.
(vi) Option to enable or disable the list of all the forecasts.
(vii) The number of months to use the routing model.

The bottom of Table 4 gives an example of this procedure, where the name of *infile* is INFOR. When you run the program in batch, the program will echo the prompts to the screen.

TABLE 4

Example of a run of the program EXTNIG
(The bold letters indicate the user input)

```
C:\FORC
 ENTER OUTPUT FILE NAME
F20881.OUT
 ENTER T_FILE FOR THE FORECASTING
T_ON6712.DAT

 FILE DESCRIPTOR FOR END OF MONTH ELEVATIONS
L681.DAT

 FILE DESCRIPTOR FOR NIAGARA RIVER FLOWS DATA SET
NIAGARA.DAT

      1536 DATA POINTS INPUT
 ENTER NUMBER OF YEARS TO FORECAST (<=7)
3
 DO YOU WANT TO LISTS ALL THE FORECASTS?
N
 NUMBER OF MONTHS TO USE ROUTING MODEL?
6
Months to update initial mean :           0
Stop - Program terminated.


        List of file INFOR

F20881.OUT
T_ON6712.DAT
L681.DAT
NIAGARA.DAT
3
N
6
```

The file INFOR can be used to run the program in batch using the command

PARED < INFOR

TABLE 5

Example of a file with end-of-month elevations

BEGINNING OF MONTH ELEVATION FOR ROUTING FORECASTS
1988 1 NUMBER OF YEARS = 20

577.78	573.43	570.41
578.32	573.56	570.46
578.84	573.99	570.09
578.95	574.03	570.96
579.19	574.06	570.81
579.90	575.21	572.35
579.94	575.07	571.85
579.85	574.83	571.86
579.45	574.74	571.60
578.45	573.87	570.70
578.42	574.24	571.11
578.54	573.61	570.47
579.40	574.58	571.45
578.88	574.15	571.15
578.67	574.23	571.33
578.94	574.38	571.33
579.21	574.98	571.66
579.64	574.59	571.34
580.72	575.93	572.58
580.74	576.08	573.21
578.93	574.50	571.60

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